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# Characterization Well R-7 Completion Report

Los Alamos NATIONAL LABORATORY

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*Produced by the Environmental Restoration Project Groundwater Investigations Focus Area*

*Cover photo shows a modified Foremost DR-24 dual-rotary drill rig. The DR-24 is one of several drill-rig types being used for drilling, well installation, and well development in support of the Los Alamos National Laboratory Hydrogeologic Workplan. The Hydrogeologic Workplan is jointly funded by the Environmental Restoration Project and Defense Programs to characterize groundwater flow beneath the 43-square-mile area of the Laboratory and to assess the impact of Laboratory activities on groundwater quality. The centerpiece of the Hydrogeologic Workplan is the installation of up to 32 deep wells in the regional aquifer.*

ENVIRONMENTAL RESTORATION PROJECT

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Los Alamos NATIONAL LABORATORY
Los Alamos NM 87545

Produced by the Groundwater Investigations Focus Area

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### List of Acronyms and Abbreviations

| | |
|---|---|
| AIT | array induction tool |
| API | American Petroleum Institute |
| APS | accelerator porosity sonde |
| APT | accelerator porosity tool |
| ASTM | American Society for Testing and Materials |
| BD | below detection |
| bgs | below ground surface |
| BMP | best management practices |
| CATMS | cations analyzed by mass spectrometry |
| CMR | combinable magnetic resonance |
| cps | counts per second |
| CVAA | cold vapor atomic absorption |
| DLS | (instrument) detection limits |
| DO | dissolved oxygen |
| DOC | dissolved organic carbon |
| DOE | (U.S.) Department of Energy |
| DR | dual rotation |
| DTH | down the hole |
| DX | Dynamic Experimentation (Division) |
| EES-1 | Geology and Geochemistry Group |
| EES-6 | Hydrology, Geochemistry and Geology Group |
| EM | electromagnetic induction |
| EPA | Environmental Protection Agency |
| ER | Environmental Restoration (Project) |
| ESH-18 | Water Quality Group |
| FIMAD | Facility for Information Management, Analysis, and Display |
| FIP | field implementation plan |
| FMI | formation microimager |
| FSF | field support facility (part of the Environmental Restoration Project) |
| ft MSL | feet above mean sea level |
| FY | fiscal year |
| GC/MS | gas chromatography/mass spectrometry |
| GEL | General Engineering Laboratories |
| GFAA | graphite furnace atomic absorption |
| GPS | global positioning system |
| GR | gamma radiation |
| HA | health advisory |

| | |
|---|---|
| HAA | hydride atomic absorption |
| HE | high explosive |
| HMX | octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine |
| HNGS | hostile environment natural gamma sonde |
| HPLC | high-performance liquid chromatography |
| HSA | hollow-stem auger |
| IC | ion chromatography |
| ICPES | inductively coupled plasma atomic emission spectroscopy |
| ICPMS | inductively coupled (argon) plasma mass spectrometry |
| ICPOES | inductively coupled (argon) plasma optical emission spectroscopy |
| I.D. | inner diameter |
| IRMS | isotope-ratio mass spectrometry |
| ISE | ion-selective electrode |
| J value | estimated value |
| JMML | Jemez Mountains meteoric line |
| LANL | Los Alamos National Laboratory |
| LDT | lithodensity tool |
| LIKPA | laser-induced kinetic phosphorimetric analysis |
| Ma | mega-annum; million years |
| MCL | maximum contaminant level |
| MDA | minimum detectable activity |
| MOU | memorandum of understanding |
| MP | multiport |
| NAD | North American Datum |
| NMED | New Mexico Environment Department |
| NMR | nuclear magnetic resonance |
| NMWQCC | New Mexico Water Quality Control Commission |
| NTU | nephelometric turbidity unit |
| O.D. | outer diameter |
| PAHs | polycyclic aromatic hydrocarbons |
| PCB | polychlorinated biphenyl |
| PID | photoionization detector |
| PPE | personal protection equipment |
| QA | quality assurance |
| QXRD | quantitative x-ray diffraction |
| RC | reverse circulation |
| RCRA | Resource Conservation and Recovery Act |
| RCT | radiological control technician |

| | |
|---|---|
| RDX | hexahydro-1,3,5-trinitro-1,3,5-triazine (research department explosive) |
| RL | reporting limit |
| SAIC | Science Applications International Corporation |
| SAPP | sodium acid pyrophosphate |
| SBDC | Stewart Brothers Drilling Company |
| SSHASP | Site-Specific Health and Safety Plan |
| SVOC | semivolatile organic compound |
| TA | technical area |
| TAL | target analyte list |
| TD | total depth |
| TDS | total dissolved solids |
| 3-D | three-dimensional |
| TNT | 2,4,6-trinitrotoluene |
| TOC | total organic carbon |
| UR-DTH | under-reaming down the hole |
| UTL | upper tolerance limit |
| VOC | volatile organic compound |
| WCO | wet chemical oxidation |
| WCSF | waste characterization strategy form |
| WGII | Washington Group International Incorporated |
| XRF | x-ray fluorescence |

## Metric to English Conversions

| Multiply SI (Metric) Unit | by | To Obtain US Customary Unit |
|---|---|---|
| kilometers (km) | 0.622 | miles (mi) |
| kilometers (km) | 3281 | feet (ft) |
| meters (m) | 3.281 | feet (ft) |
| meters (m) | 39.37 | inches (in.) |
| centimeters (cm) | 0.03281 | feet (ft) |
| centimeters (cm) | 0.394 | inches (in.) |
| millimeters (mm) | 0.0394 | inches (in.) |
| micrometers or microns (µm) | 0.0000394 | inches (in.) |
| square kilometers ($km^2$) | 0.3861 | square miles ($mi^2$) |
| hectares (ha) | 2.5 | acres |
| square meters ($m^2$) | 10.764 | square feet ($ft^2$) |
| cubic meters ($m^3$) | 35.31 | cubic feet ($ft^3$) |
| kilograms (kg) | 2.2046 | pounds (lb) |
| grams (g) | 0.0353 | ounces (oz) |
| grams per cubic centimeter ($g/cm^3$) | 62.422 | pounds per cubic foot ($lb/ft^3$) |
| milligrams per kilogram (mg/kg) | 1 | parts per million (ppm) |
| micrograms per gram (µg/g) | 1 | parts per million (ppm) |
| liters (L) | 0.26 | gallons (gal.) |
| milligrams per liter (mg/L) | 1 | parts per million (ppm) |
| degrees Celsius (°C) | 9/5 + 32 | degrees Fahrenheit (°F) |

## CHARACTERIZATION WELL R-7 REPORT

**by**

**William Stone, David Vaniman, Patrick Longmire, David Broxton, Mark Everett, Rick Lawrence, David Larssen**

## ABSTRACT

Well R-7 is located in upper Los Alamos Canyon, about one mile upstream of its confluence with DP Canyon. The location was selected to provide a well east of Technical Area (TA) 2 and south of TA-21, where contaminated effluent has been released. This well permits characterizing the occurrence and quality of water in both intermediate perched and regional zones of saturation. Installation of R-7 was funded by the Los Alamos National Laboratory (LANL or “the Laboratory”) Environmental Restoration (ER) Project.

The well was drilled in two phases. Phase I involved installing surface casing by hollow-stem-auger methods. Because of the Cerro Grande fire, Phase I had to be repeated. Phase II involved drilling a deep borehole by fluid-assisted, reverse-circulation, air-rotary, open-hole and casing-advance methods. R-7 was completed with three screens: two associated with perched saturation (set at 363- to 379-ft depth and 730- to 746-ft depth) and one straddling the regional water table (set 895- to 937-ft depth).

R-7 penetrated 25 ft of alluvium; 260 ft of Otowi Member ash flows and 62 ft of the Guaje Pumice Bed (both in the Bandelier Tuff); and 740 ft of fanglomerate and 10 ft of Totavi-Lentil-like river gravel (both in the Puye Formation). The well provided critical samples for distinguishing two subunits of the Puye Formation: an upper pumice-poor fanglomerate; and a lower pumiceous fanglomerate, which, at R-7, is vitric and unaltered in contrast to its clay-altered character at R-9 and R-12.

Although the Guaje Pumice Bed was dry and the Cerros del Rio basalt was not present, perched saturation was encountered in the Puye Formation. The regional water table, also within the Puye, was penetrated at a depth of 903 ft (45 ft deeper than expected). Available data suggest that the vertical gradient is downward at R-7. Screens #1 and #2 were not tested for hydraulic properties because of low productivity. Screen #3 was not tested because it straddles the water table.

Two water samples were collected from the borehole during drilling, one each from the uppermost perched and regional zones of saturation. Analysis focused on potential contaminants released at adjacent technical areas. Concentrations of radionuclides, metals, and anions at R-7 were found to be less than (<) maximum contaminant levels (MCLs), action levels, and health-advisory levels. Activities of tritium (<7 pCi/L) suggest that groundwater at R-7 is unaffected by Laboratory contaminant releases.

## 1.0 INTRODUCTION

R-7 is located in the east-central portion of the Laboratory (Figure 1.0-1). More specifically, the well is located in the narrow, upper part of Los Alamos Canyon, between the Omega West reactor and the mouth of DP Canyon. Lying east of TA-2 and south of TA-21, it is in a good position to characterize groundwater occurrence and quality of water in both perched and regional zones of saturation near sites of known contaminant effluent release.

The well was installed for the ER Project by the Groundwater Investigations Focus Area. Work was pursued in accordance with the "Hydrogeologic Workplan" (LANL 1998, 59599) and in support of the Laboratory’s "Groundwater Protection Management Program Plan" (LANL 1995, 50124).

The purpose of this report is twofold: (1) to describe and document the drilling, construction, and development activities associated with installation of R-7; and (2) to present preliminary interpretations of some geologic, hydrologic, and geochemical observations. Discussion of other observations is deferred until they have been evaluated in a sitewide context along with data from other Hydrogeologic Workplan and ER Project wells.

Although R-7 is primarily a characterization well, its design and construction also meets the requirements of a Resource Conservation and Recovery Act (RCRA)-compliant monitoring well as described in the Environmental Protection Agency (EPA) RCRA Groundwater Monitoring: Draft Technical Guidance, November 1992, EPA/530-R-93-001. Incorporation of this well into a Laboratory-wide groundwater monitoring program is planned, but will be more specifically determined (e.g. sampling frequency, analytes, etc.) when the results of the R-7 characterization activities are comprehensively evaluated in conjunction with other groundwater investigations being implemented via the “Hydrogeologic Workplan” (LANL 1998, 59599).

# PART I: SITE ACTIVITIES

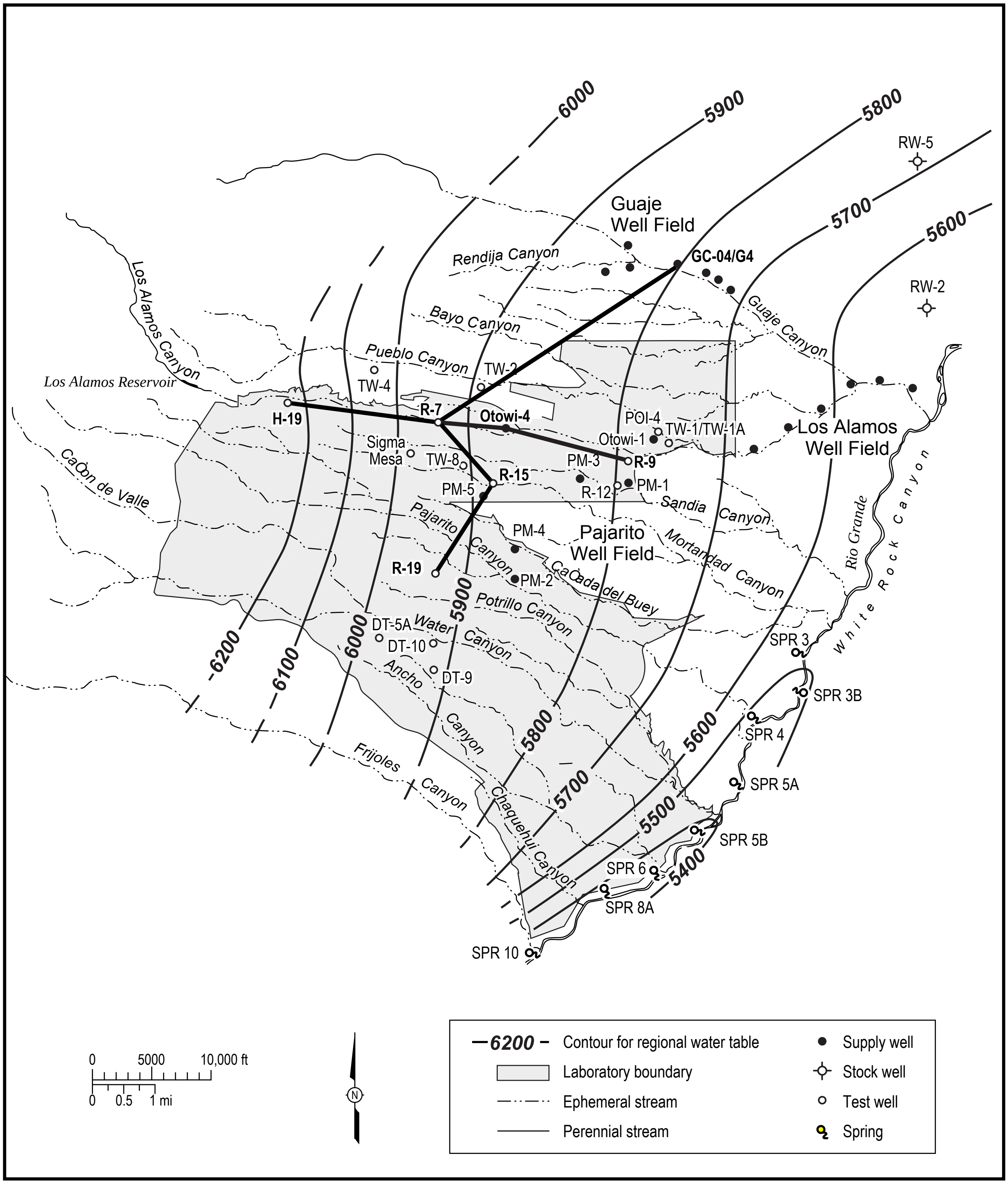
## 2.0 PRELIMINARY ACTIVITIES

Preliminary activities at R-7 included administrative preparation and site preparation. Preparatory work for the R-7 project occurred over a period of approximately five months. This timespan included preparation of the statement of work and the Field Implementation Plan (FIP).

### 2.1 Administrative Preparation

Washington Group International Incorporated (WGII) received contractual authorization to start administrative preparation tasks on November 14, 2000. Subsequently, WGII developed a Site-Specific Health and Safety Plan (SSHASP) for all entities involved in R-7 work. WGII also prepared the R-7 Waste Characterization Strategy Form (WCSF). LANL prepared the FIP to guide field personnel in the execution of R-7 drilling, construction, and sampling activities. The LANL host facility was TA-53, FMU-80. A field tenant agreement governed activities at the R-7 site in FMU-80. Additionally, a memorandum of understanding (MOU) with FMU-85 was issued for alternate site access through TA-2.

An ER Readiness Review Meeting was held on February 14, 2000, to discuss all administrative documents, permits, agreements, and plans pertaining to the R-7 project. The Groundwater Investigations Focus Area project leader signed the Readiness Review Checklist on February 18, 2000, giving authorization to begin field work.




*Note:* The line-of-section from H-19 through R-7 and O-4 to R-9 corresponds to Figure 10.3-3. The line-of-section from outcrop site GC-04 (Waresback 1986, 58715) and drill hole G-4 through R-7, R-15, and R-19 corresponds to Figure 10.3-4.

**Figure 1.0-1. Map showing the location of drill hole R-7 and other wells cited in discussion of stratigraphy**

## 2.2 Site Preparation

Wells installed under the Hydrogeologic Workplan have been drilled in two phases. Phase I drilling initially commenced at the R-7 site on February 21, 2000, with little or no formal site preparation, and was completed on February 25, 2000. The outbreak of the Cerro Grande Fire in May 2000 resulted in the temporary shutdown of the R-7 project and the postponement of further activities until November 16, 2000. Site preparation prior to Phase II drilling formally began at that time and was completed on December 9, 2000. Site preparation is discussed in more detail in Section 3.2 of this report.

# 3.0 DRILLING

Drilling activities at R-7 were completed in two phases. Phase I drilling was conducted during February 2000 by Stewart Brothers Drilling Company (SBDC) using a hollow-stem auger (HSA) to install surface conductor casing. R-7 drilling operations were interrupted by the Cerro Grande Fire, which broke out in May 2000. Phase II (deep-drilling) activities were conducted by Dynatec Drilling Company, Inc., (Dynatec) using an air-rotary, reverse-circulation (RC) system from mid-December 2000 through mid-January 2001.

The ER Project's Field Support Facility (FSF) provided drill casings, drilling bits, a small front-end loader, the dust suppression system, field-support trailers (including logging and sampling trailers), water containment tanks, drums for cuttings management, a Hermit data logger and pressure transducers, a depth-to-water meter, water sampling bailers, a diesel-powered electric generator, and water-sample testing and filtering apparatus. The Laboratory's Geology and Geochemistry Group (EES-1) provided a core-logging microscope. The Water Quality Group (ESH-18) provided a geophysical logging trailer.

The following subsections discuss Phase I drilling activities, site preparation, and Phase II drilling. Drilling and well activity shift information is summarized in Table 3.0-1. Table 3.0-2 summarizes performance statistics for well R-7. Drilling and site preparation activities are shown graphically in Appendix A.

**Table 3.0-1**
**Drilling and Shift Information for Well R-7**

| Operations Category | Dates | Number and Duration of Shifts |
|---|---|---|
| Phase I drilling/site preparation for Phase II/DR-24 rig mobilization | February 21 – 25, 2000; July 6, 2000; November 16 – December 10, 2000 | 24 12-hr |
| Phase II drilling | December 11, 2000 – January 12, 2001 | 40 12-hr |
| Borehole geophysics/ well design | January 12 – 18, 2001 | 8 12-hr |
| Well casing installation | January 18 – 21, 2001 | 6 12-hr |
| Well annular backfilling | January 21 – 31, 2001 | 20 12-hr |
| Well development/hydrologic testing | January 31 – February 8, 2001 | 17 12-hr |
| Well head construction/Westbay™ Installation/Demobilization | February 8 – March 9, 2001 | 23 8-hr |
| Total Shifts | February 21, 2000 – March 9, 2001 | 138 |

**Table 3.0-2**
**Performance Statistics for R-7**

| Drilling Types/Modes | Phase I Hollow-Stem Auger[a] | | | Phase II Fluid-Assist, Air-Rotary RC[b] Drilling[c] | | | | | Total (ft) |
|---|---|---|---|---|---|---|---|---|---|
| | 9-in. O.D. Augers | 23-in. O.D. Augers | 18-in. Surface Casing | Open Hole Mode (16-in. DTH[d] bit ) | Casing Advance Mode (13 3/8-in. casing with 14 1/2-in. UR-DTH[e] bit) | 13 3/8-in. Casing | Open Hole Mode (12 1/4-in. tricone bit) | 7-in. RC Rods | |
| Total footage drilled (ft) | 50 | 26 | 11 | 26 | 264 | 290 | 807 | 1086 | 1173 |
| Total footage rate (ft/hr) | 66.7 | 7.6 | n/a[f] | 17.7 | 12.2 | 12.2 | 14.7 | 14.1 | 14.2 |
| Bandelier tuff footage (ft)[g] | n/a | n/a | n/a | n/a | 264 | n/a | 52 | 316 | 316 |
| Bandelier tuff rate (ft/hr)[g] | n/a | n/a | n/a | n/a | 12.2 | n/a | 18.6 | 13.0 | 13.0 |
| Puye fanglomerate footage (ft) | n/a | n/a | n/a | n/a | n/a | n/a | 755 | 755 | 755 |
| Puye fanglomerate rate (ft/hr) | n/a | n/a | n/a | n/a | n/a | n/a | 14.5 | 14.5 | 14.5 |
| Trip-in footage (ft) | n/a | n/a | 11 | n/a | 26 | n/a | 3598 | 3624 | 3624 |
| Trip-in rate (ft/hr) | n/a | n/a | NR[h] | n/a | 12.0 | n/a | 103.2 | 97.8 | 97.8 |
| Trip-out footage (ft) | 50 | 26 | n/a | NR | 316 | 290 | 4340 | 4836 | 4912 |
| Trip-out rate (ft/hr) | 136.6 | 24.1 | n/a | NR | 130.6 | NR | 189.0 | 183.7 | 176.8 |

[a] HSA drilling in alluvium and Otowi Member of the Bandelier Tuff.
[b] RC = reverse circulation.
[c] RC drilling in alluvium, Otowi Member of the Bandelier Tuff, and Puye Fanglomerate.
[d] DTH = down-the-hole hammer bit.
[e] UR-DTH = under-reaming DTH bit.
[f] n/a = not applicable.
[g] Includes Otowi Member and Guaje Pumice Bed.
[h] NR = data not recorded.

## 3.1 Phase I Drilling

Phase I drilling occurred between February 21 and 25, 2000, and on July 6, 2000, (Table 3.0-1). SBDC provided a Central Mining Equipment (CME)-750 HSA drill rig equipped with small (i.e., 9-in.-outer diameter [O.D.]) and large (i.e., 23-in.-O.D.) augers. The primary goal of Phase I was to install surface conductor casing to ensure stability in the upper part of the borehole during subsequent deep drilling. The secondary goal of Phase I drilling was to produce cuttings samples for characterizing the upper 50 ft of the stratigraphic section made up of unconsolidated alluvium and underlying volcanic tuff.

On February 21, SBDC mobilized the drill rig and equipment to the R-7 site. Using small augers, drillers advanced a pilot through the alluvium and into the Otowi Member of the Bandelier Tuff to a depth of 50 ft below ground surface (bgs). Cuttings samples were collected at the surface by the shovel-scoop method at 5-ft intervals. SBDC next attempted to over-ream the borehole to total depth (TD) using large augers; however, coarse alluvial boulders prevented reaming below 13 ft bgs. At the direction of the Laboratory, a second hole was attempted with large augers at a location several feet offset from the first. At a depth of 12 ft bgs, while still in alluvium, the HSA rig experienced mechanical failure. Phase I drilling was discontinued, and surface casing was installed. A section of 18-in. steel surface casing was cemented in the hole from 0 to 11 ft bgs, with an approximate 1-ft stickup. Phase II was scheduled later, but was delayed because of the May 2000 outbreak of the Cerro Grande Fire.

On July 6, activity was resumed briefly. The R-7 surface casing was plugged with cement-bentonite slurry from 12 ft bgs to the top of the casing. This unscheduled activity was performed at the request of the Laboratory as a precaution to prevent surface water from entering the borehole in the event of flooding in Los Alamos Canyon after the Cerro Grande Fire. Further activity at the site was postponed until mid-November.

Phase I drilling at R-7 took place over the course of five daytime shifts, each of nominal 12-hr duration (Table 3.0-1). The total footage drilled by HSA was 76 ft (Table 3.0-2). Of the 76 ft, a total of 50 ft was drilled with small augers at an average rate of 66.7 ft/hr. The borehole was over-reamed using large augers to a depth of 14 ft bgs at an average rate of 7.3 ft/hr. A second borehole was drilled using large augers to a depth of 12 ft bgs at an average rate of 10.0 ft/hr. The trip-out rates for small and large augers were 136 ft/hr and 24 ft/hr, respectively (Table 3.0-2).

### 3.2 Site Preparation for Phase II Drilling

The Cerro Grande Fire resulted in the rescheduling of R-7 drilling activities and the delay of site preparation for approximately eight months after Phase I drilling was completed. Site preparation for Phase II drilling at R-7 was conducted by S. G. Western Construction Co. during November and December 2000. Activities included site clearing, access-road modification and improvement, drill-pad leveling and construction, jack-cellar installation, and lined cuttings-pit construction. Site preparation was completed in 17 daytime shifts between November 16 and December 8.

The site was initially cleared of trees, stumps, and large boulders. The site access road was graded and improved. Construction activities leveled the R-7 drill pad and laid down base-course gravel. Concurrently, a 12-ft by 60-ft pit was excavated at the north boundary of the drill pad for storage of drilling fluids and cuttings. Using a front-end loader, construction workers excavated a pit around the wellhead for a prefabricated steel jack cellar. A reinforced concrete pad was poured at the base of the pit, and the jack cellar, measuring 9-ft by 4-ft by 4-ft deep, was bolted to the pad. The exterior perimeter of the jack cellar was backfilled with native materials on November 30.

Office and supply trailers, generators, and safety lighting equipment were then moved to the site. Site preparation continued with the placement and final grading of base-course gravel to complete drill pad construction, installation of plastic sheeting to line the cuttings pit, placement of security barriers and signs, and demobilizing of construction equipment by December 8.

### 3.3 Phase II Drilling

Phase II drilling was performed by Dynatec using a fluid-assisted, RC air-rotary system capable of penetrating poorly welded volcanic tuff, basalt, and clastic sedimentary rocks to the required depths planned for R-7. The goals of phase II drilling were to produce samples of the geologic formations, permit collection of water samples, and provide a deep borehole for well installation. Throughout drilling, cuttings samples for geologic characterization were collected at 5-ft intervals using a sieve placed directly below the cyclone mouth.

For deep drilling at R-7, Dynatec furnished a Foremost™ dual-rotation DR-24 drill rig equipped with an FSF dust suppression system. In completing Phase II, open-hole and advanced-casing drilling modes were utilized with various bit sizes and types as appropriate for existing formation conditions. Air-rotary drilling was augmented with drilling fluids consisting of municipal water obtained from a Los Alamos

County fire-protection hydrant with or without nominal additives (i.e., EZ-MUD® and foam polymer) to assist in removing cuttings from the borehole.

Phase II drilling at R-7 began on December 11, 2000, and was completed on January 12, 2001. Dynatec mobilized the DR-24 rig and equipment, including drill casing, 7-in. RC rods, and bit assembly components, to the site on December 8 and 9. Drilling operations began the following day and were conducted in two 12-hr shifts per day for the duration of Phase II.

On December 11, Dynatec commenced drilling, using a 16-in. tricone carbide button bit to drill through the cement plug inside the 18-in. surface casing to 11 ft bgs. The tricone bit was then tripped out and replaced with a 16-in. down-the-hole (DTH) hammer bit, and the hole was advanced to 26 ft bgs.

On December 13, Dynatec tripped in 13 3/8-in. retractable casing and a 14 1/2-in. under-reaming DTH (UR-DTH) bit. The borehole was advanced from 26 ft to 290 ft bgs. The advanced-casing drilling mode was used to seal off perched water encountered in the alluvium. The casing string was landed at 290 ft bgs, and the 14 1/2-in. UR-DTH bit and RC rods were then tripped out of the hole, leaving the 13 3/8-in. casing in place to 290 ft bgs for the duration of Phase II drilling.

Drilling at R-7 resumed in the open-hole mode on December 16. Dynatec tripped back into the hole with a 12 1/4-in. tricone carbide button bit and advanced the borehole from 290 to 342 ft bgs. Short delays were experienced due to plugging of the bit and interchange while drilling this interval. The drill bit became plugged again and stuck at 342 ft. The bit and rods were tripped out on December 17. Dynatec decided next to return to advanced-casing drilling mode; however, the next seven shifts were spent in a failed attempt to free up the string of 13/3/8-in. casing, stuck at 290 ft bgs. Additional delays were experienced while Dynatec repaired dies for the casing jaws of the lower head that grip and turn the casing. On December 21, the casing string was successfully disconnected at ground surface level. The 12 1/4-in. tricone bit and RC rods were tripped back into the hole to 287 ft bgs. Drilling activities were suspended for the holiday break from December 21, 2000, to January 5, 2001.

Phase II drilling was resumed in open-hole mode on January 5. Dynatec advanced the 12 1/4-in. tricone bit to 387 ft bgs. Perched water was encountered, and two water samples were collected on January 6. The bit and rods were next tripped out of the hole to resolve uncertainty about the current borehole TD, determined to be 382 ft bgs.

Drilling continued in open-hole mode using the 12 1/4-in. tricone bit equipped with a 20-ft stabilizer, and the borehole was advanced from 382 ft to 1084 ft bgs with only minor delays to perform rig maintenance between January 6 and 11. The string of RC rods and bit were then tripped out of the hole in preparation for downhole geophysical logging.

On January 12 and 13, geophysical logging of the R-7 borehole (cased to 290 ft bgs) was performed by Schlumberger Oilfield Services (Schlumberger). Logging surveys performed at this time are discussed in Section 11 of this report. An attempt by WGII personnel to run a natural gamma survey, using equipment provided by the FSF, failed due to malfunctioning of the LANL gamma probe. Further delays on January 14 were due to additional repairs to the casing jaws, video logging of the borehole using the LANL video camera, and attempts to loosen the 13 3/8-in. casing string. Eventually, the casing was successfully unthreaded at 200 ft bgs. Schlumberger returned to the site to perform an array-induction-tool (AIT) survey that had been omitted from the earlier series of down-hole logs.

On January 15, Dynatec tripped back into the hole with 7-in. RC rods, a 20-ft stabilizer, and a 12 1/4-in. tricone bit to resume drilling in open-hole mode from 1084 ft bgs. The 13 3/8-in. casing was reconnected at 200 ft bgs. The borehole was advanced to 1097 ft bgs, at which point the driller reported excessive sloughing in the area around the bit. On January 16, the Laboratory declared that the R-7 borehole had reached TD; Phase II drilling activities ceased; and well design was begun. Dynatec tripped out 200 ft of 7-in. RC rod on January 16 but did not pull out the remaining string with stabilizer and 12 1/4-in. tricone bit until January 20, immediately prior to installation of the well casing.

Phase II drilling activities were completed in 40 12-hr day and night shifts (Table 3.0-1). The total footage drilled using 7-in. RC rods was 1086 ft, at an average rate of 14.1 ft/hr (Table 3.0-2).

## 4.0 WELL DESIGN AND CONSTRUCTION

The following sections describe the well-design process (performed jointly by the Laboratory and the subcontractor) and the construction of R-7.

### 4.1 Well Design

Field observations, geophysical logs, video logs, and borehole cuttings were reviewed to plan well construction. The number and placement of screens were selected to permit sampling of potential perched zones of saturation (screens #1 and #2), and to permit sampling of water at the top of the regional zone of saturation (screen #3). On-site observations during drilling of the R-7 borehole and geophysical log data indicated several zones of potential saturation above the regional water table. Two of these zones were selected to be screened. Planned and actual screen locations appear in Table 4.1-1.

**Table 4.1-1**
**Summary of Well Screen Information for R-7**

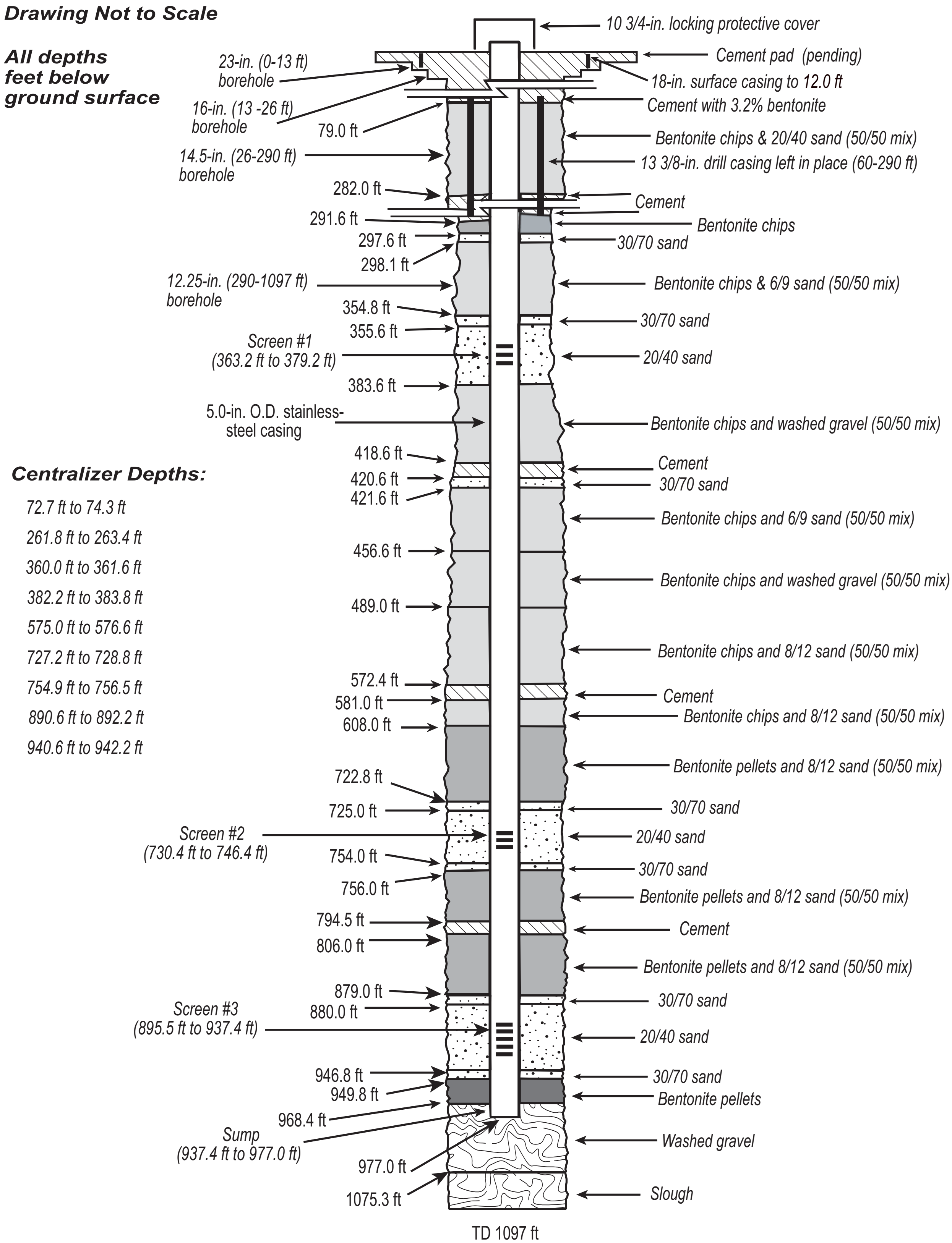
| Screen # | Planned Depth (ft) | Actual Depth (ft) | Geologic/Hydrologic Setting |
|---|---|---|---|
| 1 | 362.5–378.4 | 363.2–379.2 | Top of the Puye Formation |
| 2 | 730.1–746.0 | 730.4–746.4 | Possible perched saturation zone in Puye Formation (pumiceous) |
| 3 | 895.2–937.0 | 895.5–937.4 | Top of regional zone of saturation in Puye Formation (pumiceous) |

### 4.2 Well Construction

The construction at R-7 is shown in Figure 4.2-1. The blank casing and pipe-based screens were constructed of 304 stainless steel fabricated to American Society for Testing and Materials (ASTM) 1994 A554 standards. External couplings were also type 304 stainless steel. The couplings used were a mix of ASTM standard A312 and A511, both of which exceed the tensile strength of the threaded casing ends. The combination of coupling standards was necessary for the vendor to provide the casing materials in a timely manner, and did not compromise the integrity of the well.

The pipe-based screens were constructed of the same diameter tubing as the blank production casing (4.5-in.-inner diameter [I.D.]/5.0-in.-O.D. stainless steel). These screens were constructed by drilling 0.375-in. diameter holes in 10-ft sections of well casing and welding a wire-wrap (0.010-in. gap) over the perforated interval. The final O.D. of the screens was 5.56 in.

The bottom of the borehole when drilling terminated was 1097.0 ft bgs.The bottom of the borehole was measured at 1075.3 ft bgs with the tremie line before well casing was installed. The bottom of the well when work was completed and the screens were in place was 977 ft. The stainless-steel well components were cleaned at the well site using a hot-water cleaner and scrub brushes. Stainless-steel centralizers were installed above and below each screen and in several locations above the zone of regional saturation. All annular-fill materials were emplaced through a tremie pipe.




*Note: The screen intervals list the footages of the pipe perforations, not the tops and bottoms of screen joints.*

**Figure 4.2-1. As-built well completion diagram of well R-7**

### 4.2.1 Steel Installation

Well construction consisted of installing stainless steel and carbon steel well tubing as preparation for installation of a multiport Westbay® sampling apparatus. Dynatec installed the well tubing during the period from January 18 to 21, 2001, in six drilling shifts (Table 3.0-1).

### 4.2.2 Annular Fill Placement

A BQ-sized (1 13/16-in.-I.D.) steel tremie pipe was used to deliver annular materials to the specified design depths. Dynatec installed the annular-fill material from January 21 through January 31, 2001, in 20 drilling shifts (Table 3.0-1). Sands were emplaced across screened intervals to enhance water flow and fill the annulus. Filter pack materials were tremied using municipal water as a fluid slurry. Bentonite materials were emplaced between screened intervals to seal the annular space and prevent cross communication of waters. Bentonite was delivered using a fluid slurry consisting of EZ-MUD® (polyacrylamide-polyacrylate copolymer) mixed with municipal water. Portland cement (mixed at a ratio of 5 gal. of water for each bag of cement) was used to provide foundations for the annular fill and well-head protection of the annular space in the upper 79 ft of the borehole. During emplacement of annular fill, the field crew added approximately 22,300 gal. of municipal water.

Table 4.2-1 summarizes the annular-fill materials installed. The final configuration of the annular materials is shown in Figure 4.2-1.

**Table 4.2-1**
**Annular Fill Materials for R-7**

| Material | Amount | Unit |
|---|---|---|
| 20/40 sand[a] | 329 | bags |
| 30/70 sand[b] | 21 | bags |
| 6/9 sand[c] | 139 | bags |
| 8/12 sand[c] | 287.4 | bags |
| Benseal® bentonite[d] | 2 | bags |
| Holeplug® bentonite chips[e] | 391.5 | bags |
| Pelplug® bentonite pellets[f] | 166.5 | buckets |
| Portland® cement[g] | 82 | bags |
| Yard Art® Gravel[h] | 250.5 | bags |

[a] 20/40 sand is medium grained and used as the primary filter pack for screened intervals.
[b] 30/70 sand is fine grained and used as a secondary filter pack between the 20/40 sand and bentonite or cement.
[c] 6/9 and 8/12 sands are coarse and were used to plug formation fractures and matrix pores.
[d] Benseal® is granular bentonite that produced a slurry when mixed with water.
[e] Holeplug® is 3/8-in angular and unrefined bentonite chips.
[f] Pelplug® is 1/4-in. by 3/8-in. refined elliptical bentonite pellets.
[g] Portland® cement was mixed with municipal water at a ratio of 5 gal. per bag.
[h] Yard Art® gravel was used to fill wash-out zones.

## 5.0 WELL DEVELOPMENT

The development strategy for R-7 called for two phases and three steps for each screened interval. The preliminary phase was to include wire-brushing followed by bailing. The final phase was to involve pumping until values for field parameters met goals or could not be improved.

Development of screens #1 and #2 was not possible because of insufficient water production from these zones. Screen #3 was wire-brushed and bailed. However, it soon became apparent that productivity was also low in screen #3. It was not possible to develop screen #3 by pumping. Water rarely reached the surface, and the pump tripped off repeatedly because the pumping rate exceeded the production rate.

As a result, R-7 was developed as much as possible by bailing. Field parameters were checked at the outset of bailing and checked periodically thereafter. The ranges of values are presented in Table 5.0-1 and are shown graphically in Figure 5.0-1. The initial turbidity value was 237 nephelometric turbidity units (NTU). The withdrawal of 3000 gal. of water over a 1.5-day period reduced this figure to 21 NTU. Since turbidity hovered around 21 NTU during approximately 10 hr of bailing and did not seem to be improving, development was halted.

**Table 5.0-1**
**Development of R-7's Screen #3 by Bailing**

| Water Produced (gal.) | Range of Field Parameters[a] | | | |
|---|---|---|---|---|
| | pH | Temperature (˚C) | Specific Conductance (µS/cm)[b] | Turbidity (NTU) |
| 3000 | 7.34–6.98 | 16.2–15.2 | 214–135 | 237–20.8 |

*Note:* Only screen #3 was productive enough to develop; however, it was not productive enough to develop by pumping.

[a] Presented as values at beginning and end of development; values lower than the end value shown may have been obtained briefly during the course of development.

[b] µS/cm = MicroSiemens per centimeter.

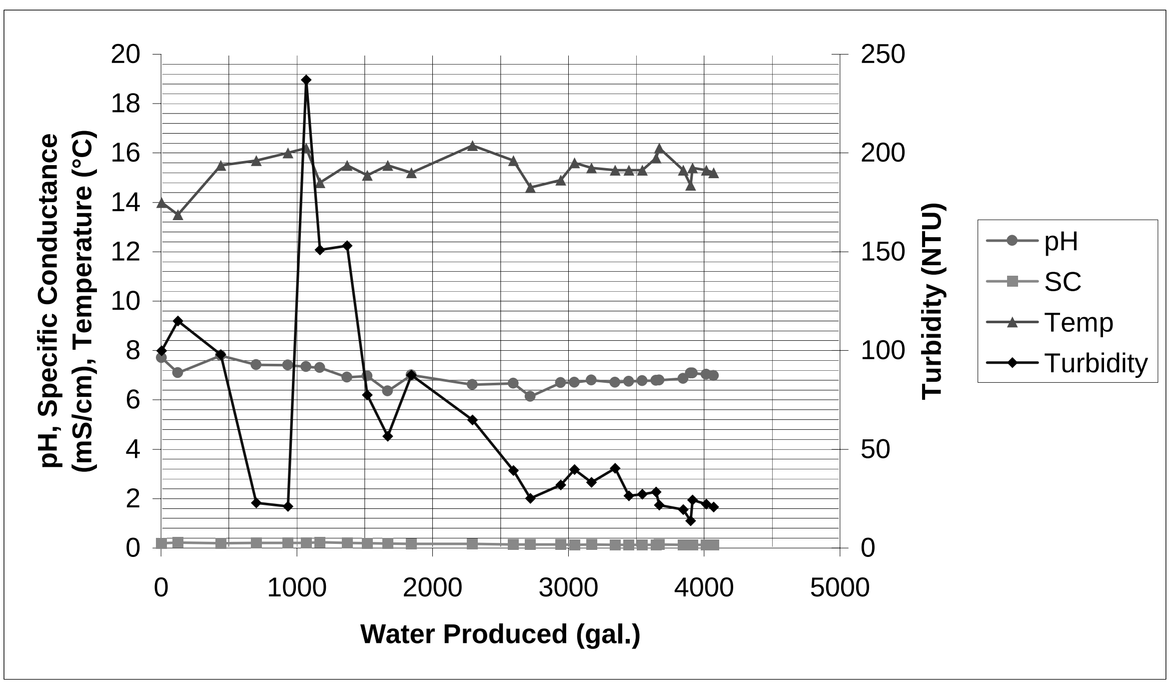



**Figure 5.0-1. Results of development by bailing for screen #3**

## 6.0 HYDROLOGIC TESTING

Neither coring nor laboratory testing of core was planned for R-7. Screens #1 and #2 were nonproductive, and screen #3 straddles the water table. Thus, field testing was not possible for screens #1 and #2 and was not appropriate for screen #3.

## 7.0 SURFACE COMPLETION AND SITE RESTORATION

The surface completion for well R-7 involved pouring a reinforced 7-ft by 12-ft by 2-ft-thick cement (5,000 psi) pad around the well casing to ensure long-term structural integrity of the well. In addition, the concrete pad supports a concrete vault, 5 ft by 10 ft by 4 ft, to protect the well and associated equipment from possible floods. The concrete pad was installed on August 6, 2001. The vault was installed on August 24, 2001. A conduit was also installed to allow for future wiring of a solar-power energy supply. A brass survey pin was installed in the northwest corner of the concrete pad.

The R-7 site was recontoured to match the surrounding topography. Before the site was recontoured, the cuttings pit was excavated; the plastic lining was removed; and the pit was refilled. In addition, the R-7 site was cleared of the slash piles created by tree removal during construction of the drill pad.

The straw wattles that are part of the R-7 site best-management-practices (BMP) installations remained in place as needed after the postoperational reclamation process. The site was physically reworked and was reseeded with a LANL-provided blend of native grasses mixed with straw mulch to facilitate reintroduction of ground cover. The canyon road and the remaining base-course area were lined with logs from the initial clearing operations to aid in traffic and erosion control.

## 8.0 INSTALLATION OF WESTBAY™ MONITORING SYSTEM

After well development was completed, a Westbay® MP55 system® for groundwater monitoring was installed in R-7. The locations of ports and packers were based on the R-7 as-built diagram, available geophysical logs, and the postcompletion video log. A Multiport (MP) Casing Installation Log shows the location of components in the well (Appendix C). A measurement port coupling and associated magnetic location collar were included in each primary monitoring zone to permit measuring fluid pressures and collecting fluid samples. A pumping port coupling was also included in the three screened zones to permit purging, sampling and hydrologic testing (Table 8.0-1). Additional measurement-port couplings were included below the pumping ports for monitoring hydraulic tests.

The casing components were set out in sequence on racks near the borehole, and casing lengths were numbered from the bottom up. Casing sections were measured with a steel tape to confirm nominal lengths. Each casing component was visually inspected, and serial numbers were recorded.

The casing components were lowered into the well on February 23, 2001, with LANL's Smeal workover rig. Each casing joint was tested with deionized water and a minimum internal pressure of 300 psi for one minute to confirm hydraulic seals. The suspended weight of the MP casing components was monitored during lowering to ensure that operating limits of the MP System were not exceeded.

After the casing was lowered into the borehole, hydraulic integrity of the casing was tested. The 30-minute test indicated that the MP casing was watertight. Next, the MP packers were inflated using deionized water (February 24 and 25, 2001). All packers were successfully inflated, and tests showed all packer valves were closed and sealed. Finally, the top of the MP casing was cut and trimmed, and a surface-completion unit was installed. The final tensile load at the top of the casing was 400 lb. The maximum limit for long-term tensile loading of the MP casing is 1000 lb.

**Table 8.0-1**
**Depths of Key Items, R-7 MP55 Completion**

| Zone No. | Screen Interval[a] (ft) | Sand Pack Interval[a] (ft) | MP Casing No. (from MP Log) | Packer No. | Packer Serial No. (0612) | Nominal Packer Position[b] (ft) | Magnetic Collar Depth (ft) | Measurement Port Depth (ft) | Pumping Port Depth[b] (ft) | Port Name | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 78 | 1 | 211 | 345.4 | | | | | |
| SQA1[c] | | | 77 | | | | | 350.0 | | SQA1 | |
| | | | 76 | 2 | 197 | 355.4 | | | | | |
| Zone 1 | 363.2 to 379.2 | 354.6 to 383.6 | 72 | | | | 375.5 | 378.0 | | MP1A[c] | |
| | | | 71 | | | | | | 383.3 | PP1[c] | |
| | | | 70 | | | | | 389.0 | | MP1B | |
| | | | 69 | 3 | 177 | 392.7 | | | | | |
| LQA1[c] | | | 68 | | | | | 397.3 | | LQA1 | |
| | | | 36 | 4 | 200 | 712.2 | | | | | |
| SQA2 | | | 35 | | | | | 716.8 | | SQA2 | |
| | | | 34 | 5 | 222 | 722.2 | | | | | |
| Zone 2 | 730.4 to 746.4 | 722.8 to 756.0 | 30 | | | | 742.3 | 744.8 | | MP2A | |
| | | | 29 | | | | | | 750.1 | PP2 | |
| | | | 28 | | | | | 755.8 | | MP2B | |
| | | | 27 | 6 | 201 | 759.5 | | | | | |
| LQA2 | | | 26 | | | | | 764.1 | | LQA2 | |
| | | | 14 | 7 | 204 | 876.0 | | | | | |
| SQA3 | | | 13 | | | | | 880.6 | | SQA3 | |
| | | | 12 | 8 | 176 | 885.9 | | | | | |
| Zone 3 | 895.5 to 957.4 | 879.0 to 949.8 | 8 | | | | 912.6 | 915.1 | | MP3A | |
| | | | 6 | | | | 932.8 | 935.3 | | MP3B | |
| | | | 5 | | | | | | 940.6 | PP3 | |
| | | | 4 | | | | | 946.3 | | MP3C | |
| | | | 3 | 9 | 219 | 950.0 | | | | | |
| LQA3 | | | 2 | | | | | 954.6 | | LQA3 | |

[a] All depths are with respect to ground level. Depths of sand pack and screened intervals are from LANL Well R-7 Completion (02/08/01).
[b] All depths of MP System casing components are the depth to the top of the respective coupling.
[c] LQA = long quality assurance. SQA = short quality assurance. MP = measurement port. PP = pumping port.

After packer inflation was completed, fluid pressures were measured at each measurement port (February 26, 2001). At that time, the formation pressures may not have recovered from the preinstallation and installation activities. Longer-term monitoring may be required to establish representative fluid pressures. All of the measurement ports operated normally. Each of the packers was supporting a differential hydraulic pressure, indicating the presence of packer seals.

A model 2523 MOSDAX® system sampler probe will be used in conjunction with the MP system to collect groundwater samples from the well.

## 9.0 GEODETIC SURVEY OF COMPLETED WELL

The location of R-7 was determined by a geodetic survey on October 10, 2001, using a Trimble 4000 SSE Global Positioning System (GPS) and a Wild/Leica TC 1000 total station. Control for horizontal coordinates was provided by the GPS tied to the LANL labwide control network through monument DEM4 at TA21. Elevation was established with the total station tied to the labwide network through DEM4. Field measurements were reduced using LisCad Plus® 5.0 surveying software.

The survey focused on two points of reference: the top of the stainless-steel well casing, and a brass monument imbedded in the northwest corner of the concrete well pad (Table 9.0-1). Horizontal well coordinates, expressed in feet, are referenced to the New Mexico State Plane Grid System, Central Zone (North American Datum, 1983 [NAD 83]). Elevation is expressed as feet above mean sea level relative to the National Geodetic Vertical Datum of 1929. The Facility for Information Management, Analysis, and Display (FIMAD) location identification number for R-7 is LA-10041.

**Table 9.0-1**
**Geodetic Data For Well R-7**

| Reference Point | Easting (ft) | Northing (ft) | Elevation (ft) |
|---|---|---|---|
| Top of Casing | 1631673 | 1773650 | 6780.5 |
| Brass Monument | 1631666 | 1773653 | 6779.2 |

# PART II: ANALYSES AND INTERPRETATIONS

## 10.0 GEOLOGY

The placement of well R-7 is shown in Figure 1.0-1. This figure also shows the locations of two interpretive lines-of-section through drill holes H-19, R-7, O-4, and R-9 along Los Alamos Canyon and from drill hole R-19 (augmented by the nearby Puye Formation measured section GC-04; Waresback 1986, 58715) through drill holes R-15, R-7, and G-4.

Geologic units encountered in R-7 consist of, in descending order: alluvium, the Otowi Member of the Bandelier Tuff including the basal Guaje Pumice Bed; an upper sequence of pumice-poor fanglomerate deposits of the Puye Formation; a lower sequence of pumiceous sediments currently assigned to the Puye Formation; and quartzite-rich Puye river gravels (related to the Totavi Lentil of the Puye Formation, but with insufficient Precambrian-rock detritus to be classified as Totavi). Depths and elevations of the contacts between these units are shown in Figure 10.0-1, with a comparison to the predicted stratigraphy based on the 3-D Geologic Model available at the time drilling began. The most notable differences between the predicted and as-drilled stratigraphy are the absence of Cerros del Rio lavas and the lack of sediments representing the Santa Fe Group below 973 ft depth. In addition to these differences, the Puye Formation from 347- to 1087-ft depth consists of two distinctive subunits: an upper pumice-poor fanglomerate; and a lower pumiceous section that includes fanglomerates, pumice falls that have probably been reworked, and minor gravel beds that appear to represent local stream systems. The regional water table occurs within this lower unit, which correlates with similar pumiceous Puye deposits in drill holes R-9, R-12, R-15, and R-19. This unit is thicker, less altered, and better represented in R-7 than in any of these earlier drill holes. Because of the widespread occurrence of this Puye subunit and the lack of any known surface outcrops, much of this section of the report is focused on the description and definition of Puye subunits.

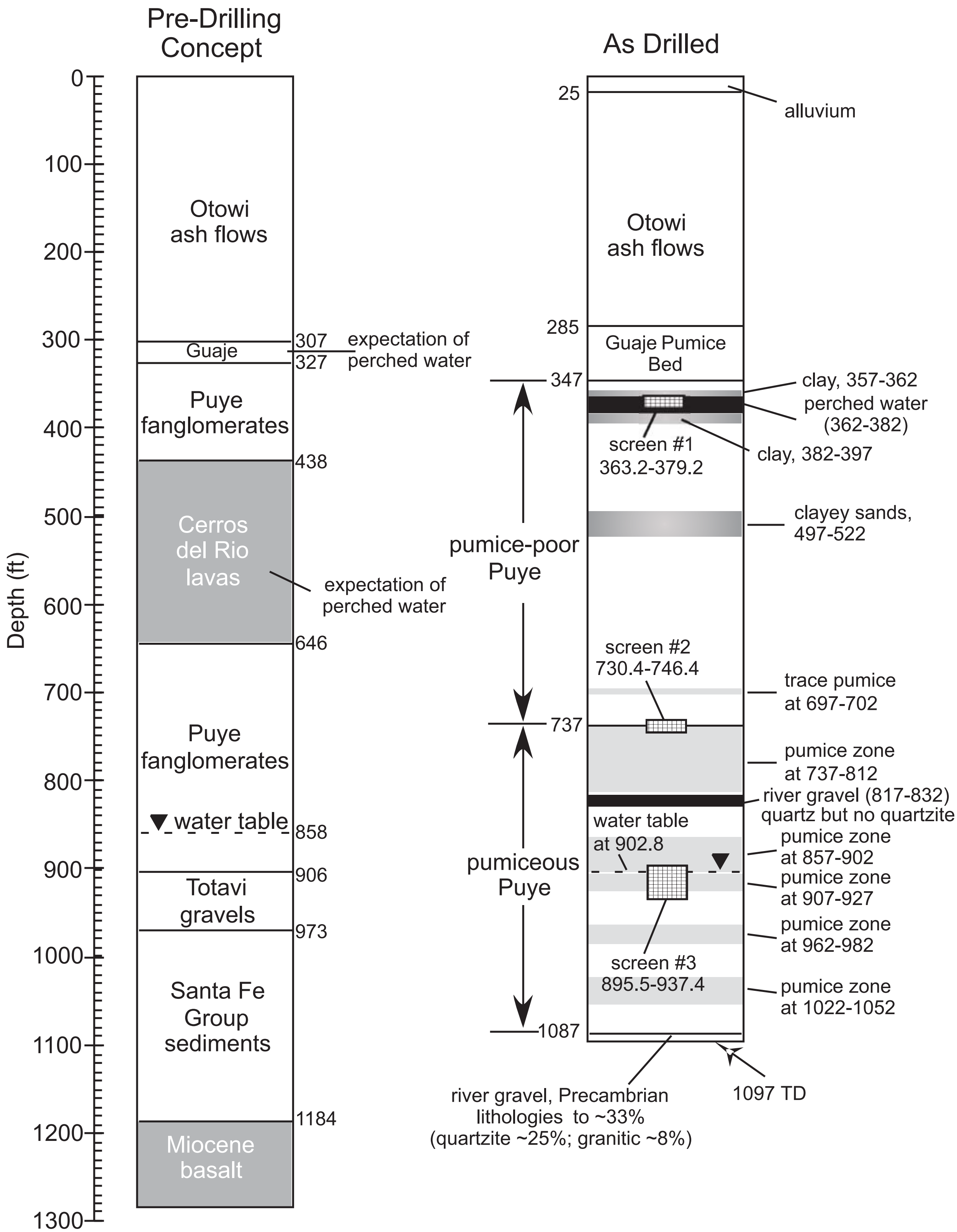



**Figure 10.0-1. The stratigraphy predicted prior to drilling of R-7 compared with the as-drilled stratigraphy**

Descriptions of geologic units at R-7 are based on examination of cuttings, geophysical logs, and laboratory examination of borehole materials. No core was collected at R-7, but cuttings were collected by reverse circulation, minimizing admixture of materials from upper portions of the borehole. As in previous R-series drill-hole reports, most of the sediments selected for examination represent the 2- to 4-mm size fraction, which was found to characterize systematic lithologic differences within the Puye Formation at R-19 (Broxton et al. 2001, 71253). Use of a common cuttings size fraction provides a basis for hole-to-hole comparison of stratigraphy in the current drilling program.

Cuttings samples were used to gather petrographic, mineralogic, and geochemical data from the lower part of the Otowi Member through the quartzite-bearing Puye river gravels at TD. Petrographic data were obtained both by binocular-microscope examination of cuttings at the site and by petrographic microscope using thin sections prepared from representative cuttings samples (Appendix C). Mineralogic data were obtained by quantitative x-ray diffraction (QXRD). Geochemical data were collected from cuttings samples by x-ray fluorescence (XRF). The data obtained by these methods are summarized in Tables 10.0-1 through 10.0-4.

The petrographic, XRF, and XRD analyses provide the basic information needed to correlate stratigraphic units of the Puye Formation and to define those aspects of lithology that relate to past water-rock interaction and evaluation of future hydrogeologic impact. The role of stratigraphic correlation is particularly important to construction of a valid 3-D geologic model for the Laboratory. R-7 provides a complete sequence through the upper Puye to quartzite-bearing river gravels that is unmatched in other R-series drill holes, providing a unique opportunity to collect data necessary for stratigraphic correlation and revision of the Laboratory 3-D Geologic Model.

Figure 10.0-1 shows the locations of screened intervals in the completed well at R-7 in relation to the borehole stratigraphy. Geologic samples at screen locations are particularly important for relating geochemistry, petrology, mineralogy, and sedimentology to hydraulic properties as well as the interpretation of water chemistry for quarterly samples. The preliminary data for evaluating these relations are provided in this report; other analyses may be appropriate in evaluating data to be obtained in the future.

## 10.1 Alluvium (0- to 25-Ft Depth)

Alluvium was encountered from 0- to 25-ft depth at R-7. The drill site at R-7 was ~25 ft to the south and ~12 ft above the stream channel in Los Alamos Canyon, located on older alluvial fill above the active stream channel. At this site, the alluvial material is coarse and unsorted, with dacitic boulders of the Tschicoma Formation and boulders of Bandelier Tuff up to ~1 m in diameter. Characterization of the alluvial system was not one of the objectives at R-7; therefore samples of alluvium were not collected for analysis.

## 10.2 Bandelier Tuff (25- to 347-Ft Depth)

The Otowi Member of the Bandelier Tuff is present at R-7, including thick upper ash flows and the basal Guaje Pumice Bed. Some description of these units is provided in this report, but detailed petrologic, geochemical, and mineralogical data were not collected because such data are available from nearby drill hole LAOI-1.1, upstream to the west.

**Table 10.0-1**
**XRF and XRD Analyses of Pumice-Poor Puye Fanglomerates from R-7**

| Sample | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Sample Depth[a] | R7 367-372 | R7 372-377 | R7 482-487 | R7 567-572 | R7 667-672 | R7 722-727 |
| Size Fraction | 2- to 4-mm | 2- to 4-mm | 2- to 4-mm | 2- to 4-mm | 2- to 4-mm | 2- to 4-mm |
| ***XRF Data*** | | | | | | |
| $SiO_2$ % | 68.88 | 68.75 | 68.62 | 68.63 | 68.87 | 68.83 |
| $TiO_2$ % | 0.438 | 0.440 | 0.442 | 0.420 | 0.403 | 0.413 |
| $Al_2O_3$ % | 14.72 | 14.69 | 14.55 | 14.64 | 14.38 | 14.30 |
| $Fe_2O_3$ % | 3.12 | 3.10 | 3.20 | 3.17 | 3.01 | 3.03 |
| MnO % | 0.049 | 0.049 | 0.062 | 0.055 | 0.056 | 0.060 |
| MgO % | 1.04 | 1.02 | 1.16 | 1.37 | 1.42 | 1.56 |
| CaO % | 2.27 | 2.26 | 2.47 | 2.55 | 2.39 | 2.46 |
| $Na_2O$ % | 3.87 | 3.93 | 3.75 | 3.82 | 3.84 | 3.83 |
| $K_2O$ % | 3.77 | 3.85 | 3.69 | 3.75 | 3.88 | 3.84 |
| $P_2O_5$ % | 0.097 | 0.099 | 0.117 | 0.148 | 0.118 | 0.140 |
| LOI %[b] | 0.80 | 0.80 | 0.72 | 0.69 | 0.66 | 0.51 |
| Total % | 99.05 | 98.99 | 98.79 | 99.24 | 99.04 | 98.98 |
| V ppm | 32 | 31 | 42 | 41 | 43 | 32 |
| Cr ppm | 31 | 36 | 32 | 36 | 38 | 51 |
| Ni ppm | 26 | 26 | 24 | 27 | 20 | 29 |
| Zn ppm | 40 | 32 | 48 | 49 | 50 | 46 |
| Rb ppm | 102 | 103 | 94 | 94 | 107 | 113 |
| Sr ppm | 325 | 333 | 359 | 347 | 327 | 325 |
| Y ppm | 19 | 23 | 33 | 17 | 19 | 19 |
| Zr ppm | 170 | 177 | 164 | 160 | 150 | 159 |
| Nb ppm | 25 | 41 | 21 | 18 | 30 | 26 |
| Ba ppm | 882 | 901 | 1013 | 937 | 806 | 884 |
| ***XRD Data*** | | | | | | |
| smectite | 5.3 | 4.7 | 1.0 | — | — | — |
| kaolinite | — | — | — | — | — | — |
| tridymite | 8.4 | 9.2 | 10.0 | 10.9 | 9.9 | 11.6 |
| cristobalite | 12.5 | 12.1 | 11.4 | 10.5 | 10.8 | 11.1 |
| quartz | 1.9 | 1.3 | 2.0 | 1.1 | 1.4 | 0.8 |
| alkali feldspar | 20.7 | 21.3 | 21.7 | 24.1 | 20.3 | 22.2 |
| plagioclase | 35.7 | 35.8 | 36.7 | 38.1 | 36.1 | 38.5 |
| glass | 10.4 | 10.2 | 14.5 | 13.0 | 16.1 | 10.0 |
| hematite | 1.3 | 1.0 | 1.2 | 2.4 | 1.2 | 1.3 |
| mica | 2.6 | 1.9 | 1.4 | 2.4 | 1.9 | 2.5 |
| hornblende | — | — | — | — | — | — |

*Note:* XRF data reported in weight percent or parts per million. XRF analytical errors (2σ) are $SiO_2$, 0.7; $TiO_2$, 0.01; $Al_2O_3$, 0.2; $Fe_2O_3$, 0.06; MnO, 0.01; MgO, 0.08; CaO, 0.1; $Na_2O$, 0.1; $K_2O$, 0.05; $P_2O_5$, 0.01; V, 10; Cr, 8; NI, 10; Zn, 12; Rb, 5; Sr, 25; Y, 6; Zr, 30; Nb, 7; and Ba, 50. XRD data reported in weight percent. XRD analytical errors (2σ) are ~5% of the amount reported for abundances >10% and ~10% of the amount reported for abundances <10%.

[a] Number ranges indicate depth of cuttings in feet.

[b] LOI = loss on ignition.

**Table 10.0-2**
**XRF and XRD Analyses of Pumiceous Puye Sediments from R-7**

| Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Sample Depth[a] | R7 737-742 | R7 742-747 | R7 817-827 | R7 882-887 | R7 902-907 | R7 917-927 | R7 927-932 | R7 1057-1062 |
| Size Fraction | 2- to 4-mm | 2- to 4-mm | 2- to 4-mm | 2- to 4-mm | 2- to 4-mm | 2- to 4-mm | 2- to 4-mm | 2- to 4-mm |
| ***XRF Data*** | | | | | | | | |
| $SiO_2$ % | 69.36 | 70.79 | 65.51 | 71.31 | 66.51 | 72.21 | 69.09 | 65.85 |
| $TiO_2$ % | 0.370 | 0.354 | 0.676 | 0.284 | 0.552 | 0.228 | 0.399 | 0.620 |
| $Al_2O_3$ % | 14.02 | 13.54 | 14.75 | 12.53 | 14.52 | 12.62 | 13.65 | 14.86 |
| $Fe_2O_3$ % | 2.83 | 2.43 | 4.34 | 1.73 | 3.64 | 1.51 | 2.51 | 4.11 |
| MnO % | 0.062 | 0.063 | 0.077 | 0.079 | 0.074 | 0.073 | 0.070 | 0.067 |
| MgO % | 1.43 | 1.11 | 1.85 | 0.54 | 1.51 | 0.49 | 1.00 | 1.70 |
| CaO % | 2.24 | 1.88 | 3.64 | 1.19 | 2.91 | 0.99 | 1.95 | 3.65 |
| $Na_2O$ % | 3.72 | 3.57 | 3.83 | 2.88 | 3.49 | 3.10 | 3.36 | 3.74 |
| $K_2O$ % | 4.00 | 4.35 | 3.21 | 4.71 | 3.27 | 4.65 | 3.96 | 2.84 |
| $P_2O_5$ % | 0.129 | 0.111 | 0.258 | 0.080 | 0.189 | 0.060 | 0.137 | 0.240 |
| LOI %[b] | 0.80 | 1.60 | 1.22 | 3.88 | 2.30 | 3.61 | 2.96 | 1.38 |
| Total % | 98.96 | 99.80 | 99.36 | 99.22 | 98.97 | 99.53 | 99.10 | 99.06 |
| V ppm | 39 | 26 | 81 | 22 | 62 | 21 | 37 | 72 |
| Cr ppm | 46 | 27 | 33 | 9 | 29 | <8 | 18 | 24 |
| Ni ppm | 29 | 19 | 22 | <11 | 16 | <12 | <11 | 23 |
| Zn ppm | 41 | 39 | 50 | 42 | 51 | 37 | 54 | 51 |
| Rb ppm | 116 | 114 | 71 | 118 | 71 | 110 | 89 | 57 |
| Sr ppm | 293 | 250 | 519 | 129 | 463 | 125 | 304 | 600 |
| Y ppm | 28 | 22 | 36 | 29 | 27 | 31 | 25 | 10 |
| Zr ppm | 151 | 148 | 164 | 110 | 158 | 116 | 139 | 162 |
| Nb ppm | 29 | 26 | 23 | 30 | 22 | 26 | 23 | 25 |
| Ba ppm | 802 | 700 | 954 | 556 | 980 | 552 | 801 | 1176 |
| ***XRD Data*** | | | | | | | | |
| smectite | — | — | 4.6 | 1.0 | 4.0 | — | 4.0 | 4.0 |
| kaolinite | — | — | — | — | 0.2 | — | 0.2 | — |
| tridymite | 9.0 | 5.9 | 3.1 | — | 4.2 | — | 2.4 | 3.4 |
| cristobalite | 10.0 | 7.3 | 6.3 | 1.5 | 5.4 | 1.2 | 3.3 | 8.3 |
| quartz | 1.0 | 1.0 | 1.9 | 1.0 | 2.5 | 0.7 | 1.2 | 0.9 |
| alkali feldspar | 19.1 | 13.6 | 11.6 | 3.8 | 9.9 | 2.3 | 6.1 | 9.9 |
| plagioclase | 33.3 | 25.7 | 39.5 | 9.7 | 31.7 | 7.1 | 20.9 | 43.1 |
| glass | 23.6 | 41.6 | 27.9 | 81.1 | 41.1 | 87.0 | 61.1 | 28.1 |
| hematite | 1.3 | 0.8 | 0.9 | 0.2 | 0.6 | 0.1 | 0.2 | 1.0 |
| mica | 1.3 | 1.6 | 0.5 | — | 1.2 | 0.4 | 0.4 | 0.9 |
| hornblende | — | — | 0.2 | — | 0.1 | — | 0.1 | 0.2 |

*Note:* XRF data reported in weight percent or parts per million. XRF analytical errors (2σ) are $SiO_2$, 0.7; $TiO_2$, 0.01; $Al_2O_3$, 0.2; $Fe_2O_3$, 0.06; MnO, 0.01; MgO, 0.08; CaO, 0.1; $Na_2O$, 0.1; $K_2O$, 0.05; $P_2O_5$, 0.01; V, 10; Cr, 8; NI, 10; Zn, 12; Rb, 5; Sr, 25; Y, 6; Zr, 30; Nb, 7; and Ba, 50. XRD data reported in weight percent. XRD analytical errors (2σ) are ~5% of the amount reported for abundances >10% and ~10% of the amount reported for abundances <10%.

[a] Number ranges indicate depth of cuttings in feet.

[b] LOI = loss on ignition.

## Table 10.0-3
## XRF and XRD Analyses of Otowi Ash Flow and Lower Puye Formation Pumices from R-7

| Sample | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Sample Depth[a] | R7 327-332 | R7 742-747 | R7 787-792 | R7 857-862 | R7 882-887 | R7 912-917 | R7 972-977 | R7 1047-1052 |
| Stratigraphy | Otowi | Puye | Puye | Puye | Puye | Puye | Puye | Puye |
| ***XRF Data*** | | | | | | | | |
| $SiO_2$ % | 72.85 | 72.78 | 73.51 | 73.33 | 73.51 | 73.41 | 72.94 | 71.89 |
| $TiO_2$ % | 0.050 | 0.211 | 0.133 | 0.142 | 0.125 | 0.157 | 0.124 | 0.122 |
| $Al_2O_3$ % | 11.95 | 12.45 | 11.87 | 12.08 | 12.02 | 12.32 | 12.21 | 12.48 |
| $Fe_2O_3$ % | 1.54 | 1.21 | 0.82 | 0.89 | 0.82 | 1.04 | 0.81 | 0.81 |
| MnO % | 0.092 | 0.062 | 0.063 | 0.066 | 0.069 | 0.072 | 0.064 | 0.077 |
| MgO % | <0.06 | 0.21 | 0.16 | 0.19 | 0.17 | 0.23 | 0.27 | 0.25 |
| CaO % | 0.26 | 0.78 | 0.45 | 0.48 | 0.43 | 0.56 | 0.47 | 0.56 |
| $Na_2O$ % | 3.62 | 3.05 | 2.77 | 2.62 | 2.76 | 3.07 | 2.80 | 2.44 |
| $K_2O$ % | 4.52 | 5.36 | 5.36 | 5.25 | 5.23 | 5.01 | 5.10 | 5.64 |
| $P_2O_5$ % | <0.01 | 0.034 | 0.019 | 0.022 | 0.019 | 0.025 | 0.016 | 0.018 |
| LOI % [b] | 4.06 | 3.23 | 4.17 | 4.54 | 4.43 | 3.70 | 4.48 | 5.17 |
| Total % | 98.96 | 99.38 | 99.34 | 99.62 | 99.58 | 99.59 | 99.28 | 99.46 |
| V ppm | <10 | 12 | <10 | 13 | <10 | 15 | 19 | <10 |
| Cr ppm | <8 | <8 | <8 | <8 | <8 | 16 | <8 | <8 |
| Ni ppm | <12 | <11 | <11 | <11 | <11 | <11 | <11 | <12 |
| Zn ppm | 127 | 29 | 38 | 33 | 24 | 32 | 33 | 36 |
| Rb ppm | 358 | 135 | 124 | 121 | 125 | 116 | 114 | 126 |
| Sr ppm | <7 | 94 | 27 | 38 | 25 | 38 | 37 | 57 |
| Y ppm | 120 | 24 | 29 | 37 | 27 | 37 | 31 | 27 |
| Zr ppm | 275 | 142 | 91 | 97 | 92 | 99 | 89 | 100 |
| Nb ppm | 181 | 32 | 22 | 21 | 21 | 29 | 18 | 31 |
| Ba ppm | <43 | 565 | 453 | 616 | 419 | 486 | 534 | 559 |
| ***XRD Data*** | | | | | | | | |
| smectite | — | — | — | — | — | — | 6.0 | — |
| kaolinite | — | — | — | — | — | — | — | — |
| tridymite | — | — | — | — | — | — | — | — |
| cristobalite | — | 0.3 | 0.5 | — | 0.1 | — | 0.2 | 0.2 |
| quartz | 2.4 | 0.9 | 0.6 | 0.7 | 0.6 | 0.6 | 1.0 | 0.2 |
| alkali feldspar | 1.9 | 2.2 | 1.9 | 1.2 | 2.0 | 1.8 | 2.1 | 1.7 |
| plagioclase | 1.8 | 8.3 | 2.3 | 1.0 | 2.8 | 3.7 | 2.4 | 3.8 |
| glass | 92.0 | 82.3 | 92.4 | 95.1 | 91.5 | 95.2 | 84.5 | 94.5 |
| hematite | — | — | — | — | — | — | — | — |
| mica | — | 1.9 | — | — | — | 0.2 | — | — |
| hornblende | — | 0.1 | — | — | — | — | — | — |

*Note:* XRF data reported in weight percent or parts per million. XRF analytical errors ($2\sigma$) are $SiO_2$, 0.7; $TiO_2$, 0.01; $Al_2O_3$, 0.2; $Fe_2O_3$, 0.06; MnO, 0.01; MgO, 0.08; CaO, 0.1; $Na_2O$, 0.1; $K_2O$, 0.05; $P_2O_5$, 0.01; V, 10; Cr, 8; NI, 10; Zn, 12; Rb, 5; Sr, 25; Y, 6; Zr, 30; Nb, 7; and Ba, 50. XRD data reported in weight percent. XRD analytical errors ($2\sigma$) are ~5% of the amount reported for abundances >10% and ~10% of the amount reported for abundances <10%.

[a] Number ranges indicate depth of cuttings in feet.

[b] LOI = loss on ignition.

**Table 10.0-4**
**XRF and XRD Analyses of Quartzite-Bearing River Gravels from R-7**

| Sample | 1 | 2 | 3 |
|---|---|---|---|
| Sample Depth[a] | R7 1087-1092 | R7 1092-1097 | R7 1092-1097 |
| Size Fraction | 2- to 4-mm | 2- to 4-mm | <2-mm |
| ***XRF Data*** | | | |
| $SiO_2$ % | 69.26 | 69.30 | 70.08 |
| $TiO_2$ % | 0.529 | 0.535 | 0.635 |
| $Al_2O_3$ % | 13.30 | 13.13 | 12.45 |
| $Fe_2O_3$ % | 4.07 | 4.10 | 4.71 |
| MnO % | 0.078 | 0.077 | 0.079 |
| MgO % | 1.17 | 1.21 | 1.19 |
| CaO % | 2.87 | 3.00 | 2.86 |
| $Na_2O$ % | 3.19 | 3.18 | 2.87 |
| $K_2O$ % | 3.43 | 3.32 | 2.71 |
| $P_2O_5$ % | 0.215 | 0.213 | 0.134 |
| LOI %[b] | 1.21 | 1.11 | 1.24 |
| Total % | 99.32 | 99.17 | 98.95 |
| V ppm | 67 | 64 | 95 |
| Cr ppm | 29 | 28 | 39 |
| Ni ppm | <12 | <12 | 12 |
| Zn ppm | 54 | 57 | 50 |
| Rb ppm | 89 | 81 | 68 |
| Sr ppm | 507 | 541 | 494 |
| Y ppm | 21 | 24 | 25 |
| Zr ppm | 185 | 183 | 280 |
| Nb ppm | 19 | 12 | 10 |
| Ba ppm | 980 | 946 | 794 |
| ***XRD Data*** | | | |
| smectite | 6.0 | 6.0 | 6.0 |
| kaolinite | — | — | — |
| tridymite | 3.3 | 3.4 | 1.8 |
| cristobalite | 5.1 | 4.9 | 2.2 |
| quartz | 16.1 | 19.7 | 28.3 |
| alkali feldspar | 15.2 | 15.6 | 10.4 |
| plagioclase | 34.2 | 34.6 | 33.9 |
| glass | 14.1 | 13.5 | 13.9 |
| hematite | 0.8 | 0.9 | 0.9 |
| mica | 1.4 | 1.6 | 1.4 |
| hornblende | 0.1 | 0.1 | 0.3 |

*Note:* XRF data reported in weight percent or parts per million. XRF analytical errors (2σ) are $SiO_2$, 0.7; $TiO_2$, 0.01; $Al_2O_3$, 0.2; $Fe_2O_3$, 0.06; MnO, 0.01; MgO, 0.08; CaO, 0.1; $Na_2O$, 0.1; $K_2O$, 0.05; $P_2O_5$, 0.01; V, 10; Cr, 8; NI, 10; Zn, 12; Rb, 5; Sr, 25; Y, 6; Zr, 30; Nb, 7; and Ba, 50. XRD data reported in weight percent. XRD analytical errors (2σ) are ~5% of the amount reported for abundances >10% and ~10% of the amount reported for abundances <10%.

[a] Number ranges indicate depth of cuttings in feet.

[b] LOI = loss on ignition.

### 10.2.1 Ash Flows of the Otowi Member of the Bandelier Tuff (25- to 285-Ft Depth)

R-7 penetrated 260 ft of nonwelded vitric ash flows of the Otowi Member of the Bandelier Tuff. Cuttings obtained from this interval contain fine vitric ash that is largely washed out as the cuttings are collected. Pumices in the ash flows are generally crushed to sand-size or finer during drilling and circulation through the drill pipe, leaving many cuttings samples with an overrepresentation of the harder lithic fragments from the ash flows. These lithic fragments consist predominantly of silicified intermediate-composition volcanic lithologies. The cuttings interval from 280- to 285-ft depth is exceptionally lithic-rich, suggesting presence of a lithic swarm at the base of the Otowi ash flows. Because Schlumberger logs extend only from ~260 ft to TD, little borehole geophysical information is available for the Otowi ash flows at R-7.

### 10.2.2 Guaje Pumice Bed of the Otowi Member of the Bandelier Tuff (285- to 347-Ft Depth)

In many drill holes, the Guaje Pumice Bed is marked by a distinctive rise in total natural gamma signal and in spectral gamma U and Th relative to the overlying ash flows. At R-7 this feature was partially masked by the extension of drill casing to 290-ft depth and obscured by an atypical drop in the natural gamma signal in the lower part of the pumice bed (322- to 347-ft depth). There is some uncertainty about the lower contact of the Guaje Pumice Bed; the drop in gamma signal at 322 ft could be interpreted as an indication that the bottom of the Guaje Pumice Bed is at this shallower depth. However, the gamma signal is not a reliable indicator for the Guaje Pumice Bed. (See Broxton et al., 2001, 71250). Moreover, Guaje-type pumice is distinctive in the cuttings collected from 322- to 347-ft depth. Drillers noted possible slough of material from 327 to 342 ft, but cuttings returned from 342 to 347 ft. consist of distinctive Guaje pumice.

A thin section prepared from the 2- to 4-mm cuttings at 312- to 322-ft depth, within the upper part of the Guaje Pumice Bed where the U and Th gamma signals were strongest, contains vitric Guaje pumice with little alteration. Most of the fragments in the thin section, however, are lithic clasts that include devitrified tuff, dacitic lavas, arkosic sandstone, and a muscovite-bearing quartzite (Appendix C). Such a variety of lithic clasts, including sandstone and quartzite, is unusual for the Bandelier Tuff. The occurrence of quartzite in particular is a caution against interpretation of any quartzite occurrence as an indication of the presence of axial river gravels. At present this occurrence of quartzite in the Guaje Pumice Bed is interpreted as evidence that initial Bandelier Tuff eruptions intersected small primary or reworked quartzite occurrences near the eruptive conduit.

A thin section of 2- to 4-mm fragments was also examined from the upper part (327 to 332 ft) of the sloughed interval. This thin section consists predominantly (75%) of quartz- and sanidine-porphyritic vitric pumice typical of the Guaje Pumice Bed; the rest of the fragments are of dacitic lavas and immature micaceous volcanic siltstone. A separate sample of the pumice was analyzed for chemical and mineralogical composition (sample 1, Table 10.0-3) and is typical of the most evolved lower Bandelier Tuff rhyolite compositions with high content of Y (120 ppm), Zr (275 ppm), Nb (181 ppm), and Rb (358 ppm), and with very low Sr content (<7 ppm). This rhyolite composition is distinct from the rhyolites of the lower pumiceous Puye Formation that are described below (Section 10.4).

During drilling, water circulated out of the drill hole at 332-ft depth was clay-laden. XRD analysis of the solids settled from this water show that 58% of the material was clay (57% smectite and ~1% kaolinite). The remainder was feldspar (20%), glass (15%), cristobalite (6%), quartz (2.6%), and biotite (0.6%). The occurrence of cristobalite and biotite is not typical of the Otowi Member of the Bandelier Tuff and may be related to disaggregation of sandstone or siltstone lithic fragments (as noted above), or related to introduction of these minerals with the slough. A more detailed analysis of the large amount of clay in this sample may show whether this clay was translocated or formed in place as an alteration horizon within the Guaje Pumice Bed.

### 10.3 Puye Formation (347- to 1097-Ft Depth [TD])

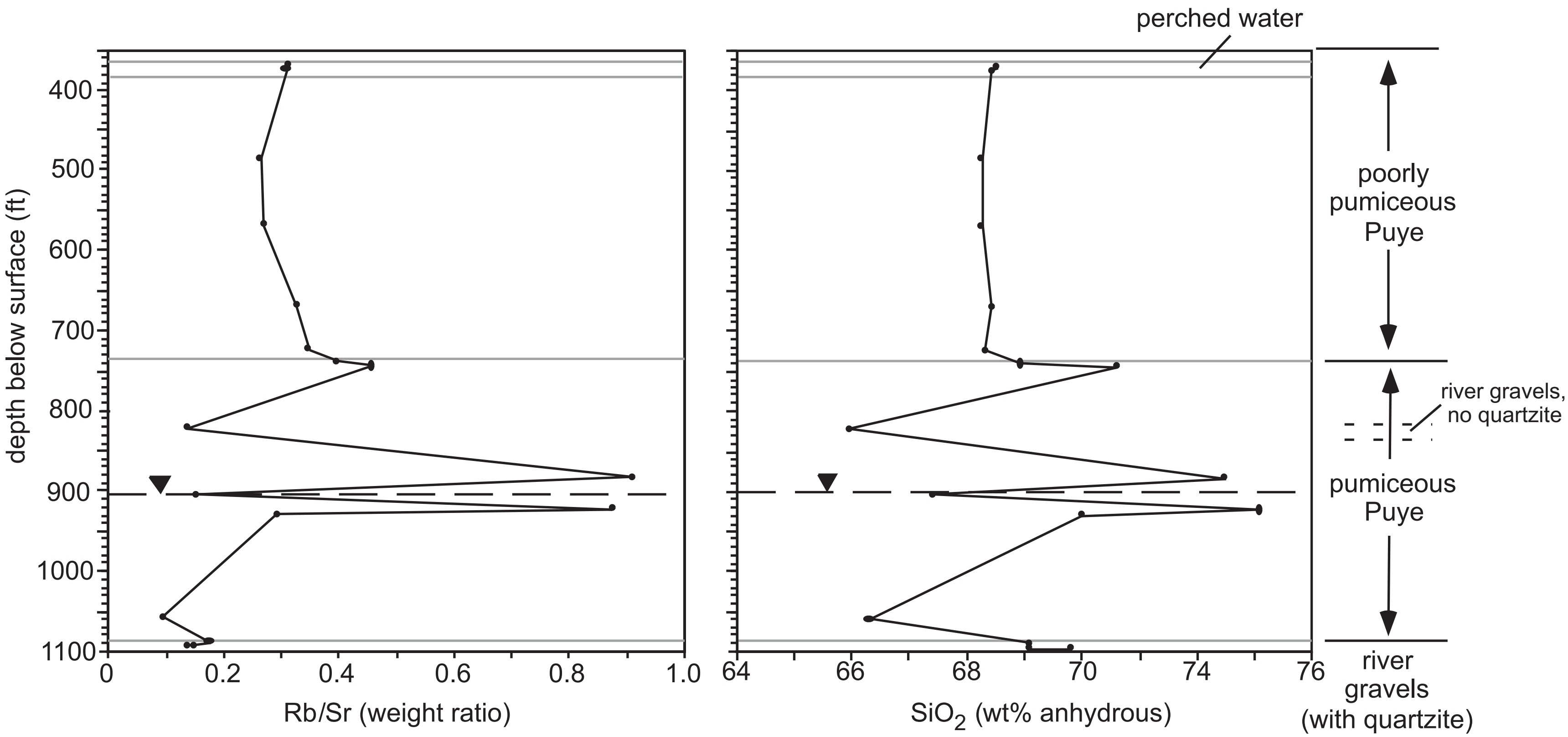
Sediments of the Puye Formation were much thicker than anticipated at R-7 (Figure 10.0-2). Recent results from the completion of R-series wells in the central Laboratory site indicate that at least two subunits of the Puye Formation can be correlated over several kilometers. These subunits include an upper portion (~220 to 400 ft) that is dominated by detritus from crystalline dacitic lavas, and a lower portion (~160 to >400 ft) with similar dacitic detritus that also contains abundant rhyolitic pumice. There also appears to be a characteristic occurrence of quartzite-rich river gravels (thickness poorly known) beneath the pumiceous Puye, but it is not yet known whether these gravels can be mapped reliably. Well R-7 provides a relatively complete and unaltered sampling of all three of these Puye subdivisions. Mineralogical and geochemical data from representative samples for these subunits are summarized in Tables 10.0-1, 10.0-2, and 10.0-4; analyses of pumice separates from the pumiceous Puye are provided in Table 10.0-3. Key features of stratigraphic importance extracted from these tables are shown in Figures 10.3-1 (geochemistry) and 10.3-2 (mineralogy). These analyses provide new insights into the nature of mappable Puye subunits for stratigraphic correlation and new understanding of lithologies that play a role in water-rock interactions.

#### 10.3.1 Pumice-Poor Puye Fanglomerates (347- to 737-Ft Depth)

The upper pumice-poor Puye fanglomerates at R-7 extend from 347- to 737-ft depth. A body of perched water was encountered near the top of this unit at 362- to 382-ft depth. The perching horizon is an underlying clay-rich zone from 382- to 397-ft depth (Figure 10.0-1). Petrographic, XRD, and XRF data indicate that the pumice-poor Puye fanglomerates at R-7 are very homogeneous, suggesting massive accumulation of volcanic detritus from very limited sources. Despite this source homogeneity, there are important variations that account for, among other things, perching of groundwater near the top of the unit.

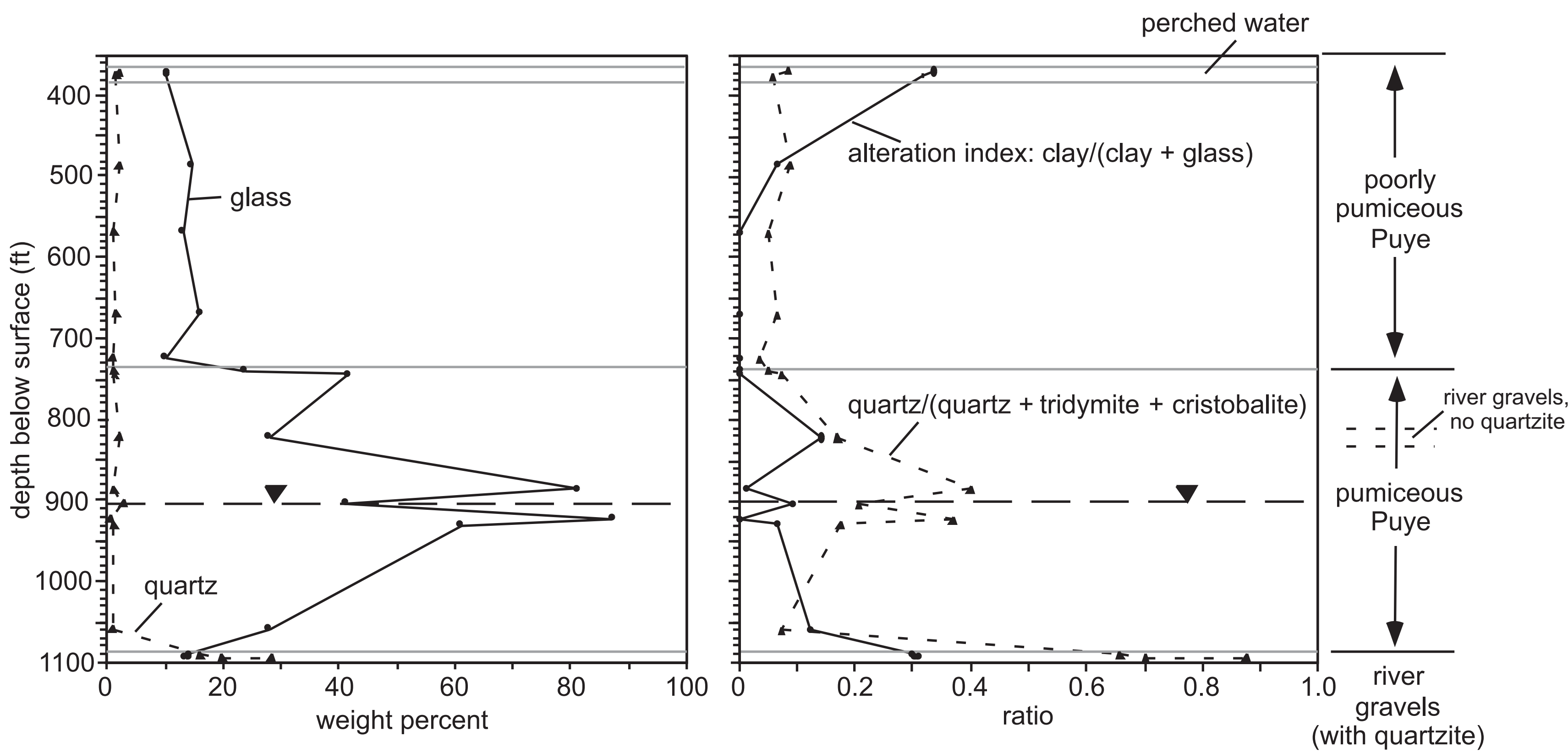
Thin sections of eight samples from this subunit were examined (Appendix C). With the exception of the sediments containing the perched water at 362- to 382-ft depth and a sandy horizon at 497- to 522-ft depth, the fanglomerates of the pumice-poor Puye at R-7 are strongly dominated by a single source lithology. This source is a set of lavas containing sieved plagioclase and characteristic acicular orthopyroxene phenocrysts, with variable occurrences of lesser clinopyroxene, amphibole, biotite, and/or quartz phenocrysts. This lithology generally constitutes between 50% and 80% of the sediments in this subunit. Samples from 667- to 672- and 722- to 727-ft depth, representing the lower ~100 ft, are essentially monolithologic, suggesting initial debris flows from a single source that were diluted by debris from other volcanic centers over time.

Other lithologies present in the R-7 pumice-poor fanglomerates are mostly from other dacitic lavas (Appendix C). Pumice is very rare, generally quartz and sanidine porphyritic, and never constitutes more than 5% of the 2- to 4-mm-size sediment samples. Two distinctive minor sequences occur. One is in the perched-water horizon at 362- to 382-ft depth. A representative sample from 367 to 372 ft contains a heterogeneous variety of dacitic lithologies, mostly quartz-bearing and some clay-altered. The other distinctive sequence consists of clayey sands at 497- to 522-ft depth. A composite sample of clayey sands from 497 to 517 ft consists of >60% volcanic siltstones and sandstones. The remainder are fragments of various dacitic lavas.




*Note:* All data are from Tables 10.0-1, 10.0-2, and 10.0-4. The values for $SiO_2$ are recalculated on a water-free (anhydrous) basis to compensate for the variable effects of glass hydration. All data are from 2- to 4-mm sediment size fractions, except for the deepest sample (1092- to 1097-ft depth) where both the 2- to 4-mm and the <2-mm size fraction of the river gravel were analyzed.

**Figure 10.3-1. Plots of Rb/Sr ratios and $SiO_2$ content in representative samples of the Puye Formation at R-7**




*Note:* All data are from Tables 10.0-1, 10.0-2, and 10.0-4. The data are from 2- to 4-mm sediment size fractions, except for the deepest sample (1092-1097 ft depth) where both the 2- to 4-mm and the <2-mm size fraction of the river gravel were analyzed.

**Figure 10.3-2. Plots of glass and quartz abundance (weight percent) and of ratios for alteration index [clay/(glass + clay)] and for quartz to all silica minerals [quartz/(quartz + tridymite + cristobalite)] in representative samples of the Puye Formation at R-7**

The homogeneity of the pumice-poor Puye sediments at R-7 can be seen in Figure 10.3-1, which shows that the ratio of Rb to Sr and the $SiO_2$ content on a water-free (anhydrous) basis are both essentially invariable. This homogeneity contrasts markedly with the extreme variation of these parameters in the underlying pumiceous Puye deposits. The upper Puye fanglomerates at R-7 have Rb/Sr ratios of 0.26 to 0.35, higher than typical of Tschicoma Formation dacitic sources in upper-level Puye fanglomerates farther to the south (0.1 to 0.2; Broxton et al. 2001, 71253). The Rb/Sr range of these fanglomerates overlaps that of axial river gravel (Totavi) deposits at drill hole R-31(0.27 to 0.37), but the fanglomerates are distinct from the quartzite-bearing river gravels in other respects. In particular, the low ratio of quartz among silica polymorphs in the pumice-poor Puye fanglomerates (Figure 10.3-2) is typical and reflects the minor abundance of quartz in the Tschicoma sources of dacitic fanglomerate detritus.

A feature worth noting in Figure 10.3-2 is the high alteration index in samples from the perched water horizon at 362- to 382-ft depth. This index is based on the ratio of alteration minerals that form from volcanic glass (typically clays but sometimes including zeolites) to the total of such minerals plus yet unaltered glass. Most of the poorly-pumiceous Puye at R-7 is essentially unaltered, but the initial glass inventory in the perched-water horizon is ~25% altered. This indicates that the perched-water horizon is long-lived and has, therefore, provided a saturated environment where hydrous alteration has been more thorough.

### 10.3.2 Pumiceous Puye Sediments (737- to 1087-Ft Depth)

Pumiceous Puye sediments at R-7 extend from approximately 737- to 1087-ft depth. A transition to higher porosity and more abundant late-decay saturation is seen at 737 ft in the Schlumberger combined magnetic resonance (CMR) borehole log (Appendices F and H). This observation is consistent with a transition to a pumice-bearing unit with abundant open pore space in pumiceous vesicles. Lack of cuttings returns from 1084 to 1087 ft leaves an uncertainty of at least 3 ft in the depth of the lower contact with quartzite-bearing river gravels.

Pumice is not uniformly abundant throughout the pumiceous subunit but occurs in at least five principal pumice-rich zones (Figure 10.0-1). Because of the importance of determining the compositions of relatively pure pumice separates for stratigraphic correlation, two types of samples were analyzed from this subunit. The first type consisted of representative 2- to 4-mm size fractions; analytical results for these are presented in Table 10.0-2. The second type of sample consisted of hand-picked pumice separates; results for these are in Table 10.0-3. Thin section descriptions of both types of samples are in Appendix C.

The representative 2- to 4-mm sediment fractions contain up to ~90% pumice (e.g., 2- to 4-mm sample at 912- to 917-ft depth), but some intercalated deposits have only traces of pumice or no pumice at all. In general, the thickness of pumiceous zones and the abundance of pumice within them tend to be greatest in the upper half of the pumiceous subunit. The alternation between zones rich in rhyolitic pumice and zones rich in dacitic lava fragments results in highly variable chemistry and mineralogy, as seen in Figures 10.3-1 and 10.3-2. The more pumice-rich zones have higher Rb/Sr, higher $SiO_2$, and more glass. All of the pumices separated for analysis (Table 10.3-3) are rhyolitic, with silica contents of ~72 to 74 wt% (75 to 77 wt% when recalculated on an anhydrous basis).

The pumices present at the top of the pumiceous subunit are moderately porphyritic (~5% phenocrysts of sanidine, albite, and quartz with less common biotite and hornblende). These porphyritic pumices occur throughout the pumiceous zones, but below ~780-ft depth, aphyric pumices predominate. All of the pumices are relatively fresh and unaltered; the alteration index (clay/[clay + glass]) is generally less than

15%, whether the sample is from above or below the water table (Figure 10.3-2). This lower amount of alteration contrasts with the greater alteration (~25%) in the perched-water horizon at 362 to 382 ft, even though the dacitic lava glass in the perched-water horizon is less porous and accessible. The lack of alteration in highly accessible glass at depth suggests a difference in the alteration effects of perched and regional saturated systems (possibly a difference in ionic strength of groundwaters).

The dacitic detritus intermixed with the pumice deposits and in abundance between the pumiceous zones is generally more mafic than that in the overlying poorly-pumiceous Puye. In thin section, the dacites in the pumiceous Puye are very heterogeneous. Most of them lack quartz phenocrysts but contain sieved plagioclase phenocrysts plus various combinations of clinopyroxene, orthopyroxene, amphibole, and biotite phenocrysts. Most sediment samples contain some fragments of vitric and in some cases vesicular dacitic lavas. The heterogeneity of dacite types and common occurrence of vitric dacitic lavas indicates detrital contributions from a number of active volcanic centers that contributed some debris from chilled flow exteriors.

An occurrence of relatively well-sorted and rounded detritus from 817- to 832-ft depth is interpreted as a local riverine deposit. The constituent lithologies at this depth are almost entirely dacitic and do not differ greatly from other dacite-rich zones in the pumiceous Puye deposits. However, binocular-microscope examination of the gravels reveals small amounts of rounded basalt fragments and large (4-mm), rounded single grains of quartz, although Precambrian quartzite was not observed. The detritus in this interval has the highest alteration index within the pumiceous Puye, possibly as a result of alteration both in a stream environment and following burial.

The Schlumberger spectral gamma log (Appendices F and H) shows a significant rise in U content beginning at 876 ft, peaking at ~883 ft, and tailing off gradually to ~909 ft, just beneath the top of regional saturation at 902.8 ft. A pumice separate from 882- to 887-ft depth within the pumiceous Puye was selected to evaluate this excursion in U content. This sample shows no unusual features in petrography (typical aphyric vitric pumice [Appendix C]) or in chemical composition (Table 10.0-3, although U cannot be determined by XRF in these samples). The cause of the anomalously high U signal in the spectral gamma log remains unknown.

### 10.3.3 Quartzite-Bearing Puye River Gravels (1087- to 1097-Ft Depth [TD])

A sequence of quartzite- and granite-bearing river gravels extends from 1087-ft depth to the TD of R-7 at 1097 ft. Drilling was stopped within this unit because of difficulty in making progress; material was being drawn in laterally rather than from beneath the bit. This problem is commonly encountered in well-rounded and uncemented river gravels.

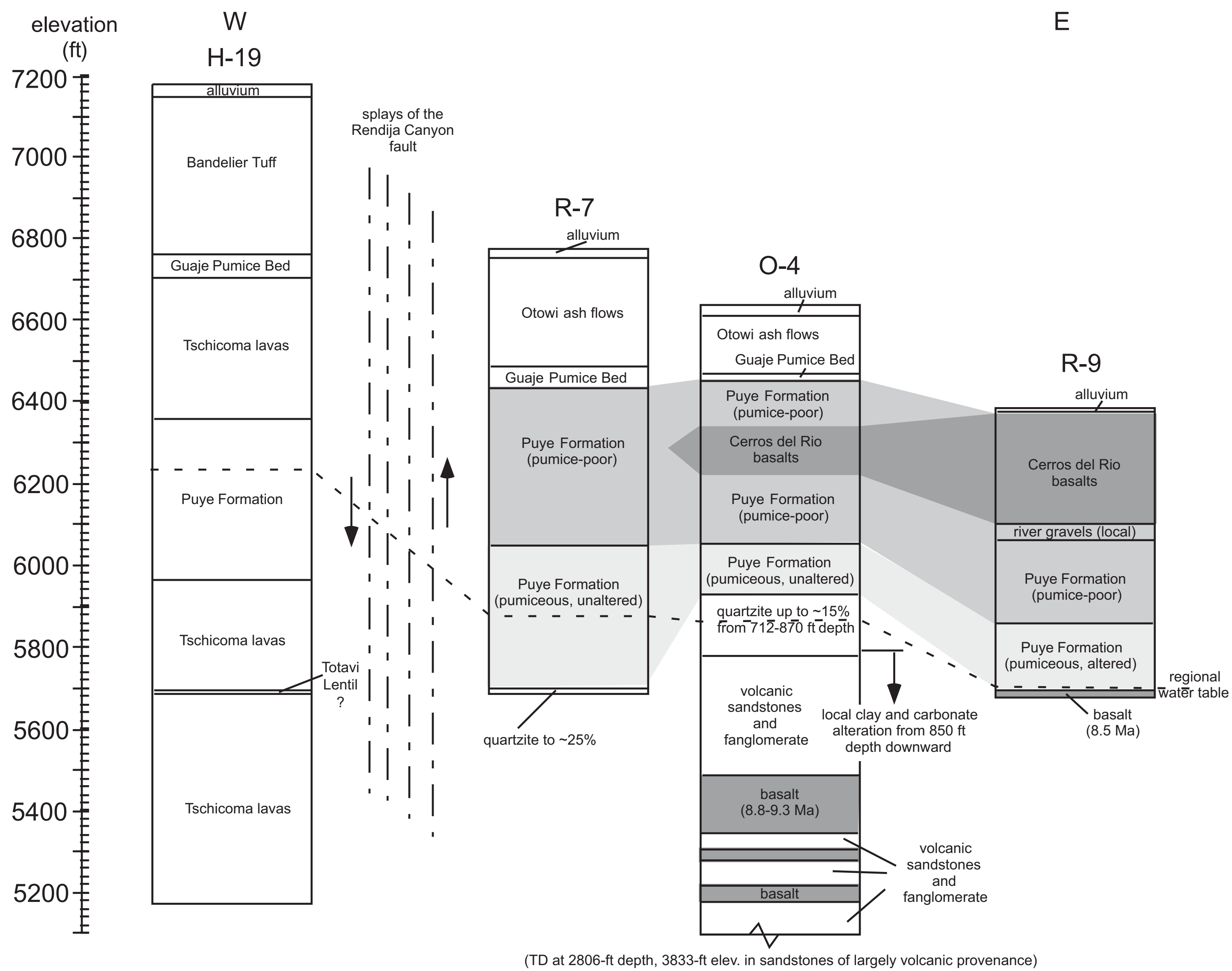
The 2- to 4-mm river gravels at this depth contain ~15-33% Precambrian quartzites and granitic lithologies, with quartzite about three times as abundant as granitic lithologies. In addition to these lithologies that are not found in the overlying Puye samples, the intermediate-composition (mostly dacitic) lavas that constitute the bulk of the samples are commonly altered, and all fragments are exceptionally well rounded. Traces of vitric aphyric pumice also occur but in very small amounts. Petrographic analysis of both large (4- to 8-mm) and smaller (<2-mm) size fractions from 1092- to 1097-ft depth show the same distribution of lithologies, although the 4- to 8-mm size fraction includes 33% of various welded devitrified tuffs, ranging from crystal-rich plagioclase-clinopyroxene-biotite porphyritic tuff to aphyric tuff (Appendix C).

The distinction between these river gravels and the overlying Puye sediments can be seen in the parameters plotted in Figure 10.3-2, particularly in the sharp rise in quartz abundance and in the increase in the ratio of quartz/(quartz + tridymite + cristobalite). The survival of detrital quartz in riverine transport and the predominance of quartz over other silica minerals in Precambrian-rock lithologies accounts for these differences from the volcanically-derived upper Puye. The mere presence of Precambrian-rock lithologies, however, is not sufficient to identify axial Rio Grande sediments (Totavi Lentil) from Puye river gravels that contain minor amounts of Precambrian-rock lithologies (perhaps redistributed from Totavi deposits). Dethier (1997, 49843) reserved the identification of Totavi (Ancestral Rio Grande) facies to river gravels with “clasts generally >80% quartzite and other resistant lithologies from northern New Mexico, but [with] clasts from the southern Sangre de Cristo Range . . . common locally.” He also noted that, “Precambrian material composes >30% of some fluvial units” within the Puye fanglomerates that are not classified as Totavi. By these definitions, which are based on detailed field studies, the quartzite-bearing river gravels in R-7 cannot be considered part of the Totavi Lentil. Nevertheless, riverine gravels with lesser quartzite abundances than the Totavi may have distinctive hydrogeologic properties and, if mappable in specific areas of interest, may be treated separately in the 3-D Geologic Model.

## 10.4 Stratigraphic Correlation of Subunits in the Puye Formation

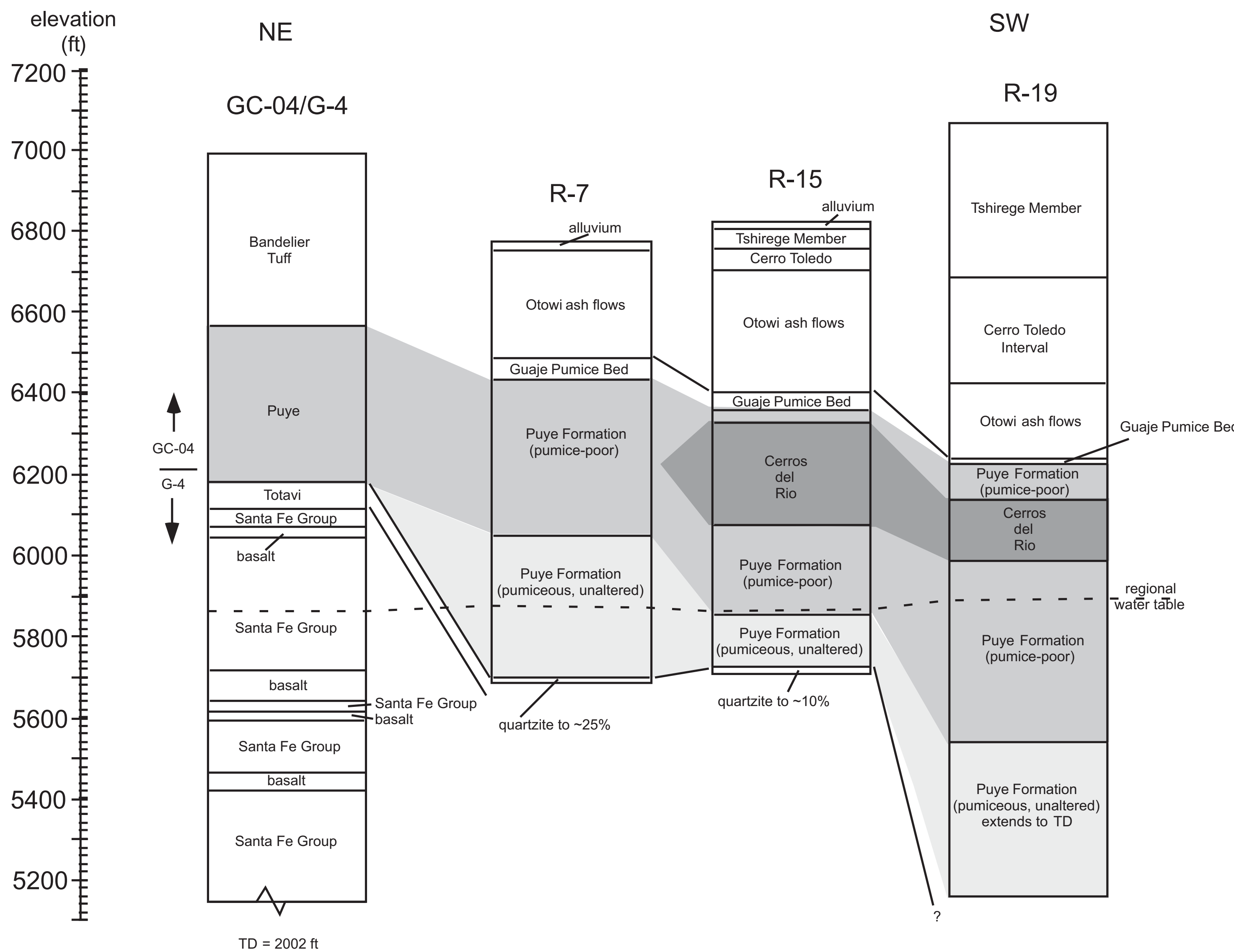
The first-order distinction within Puye sediments at R-7 is between an upper pumice-poor subunit and a lower pumiceous subunit. This same relationship has been observed in wells R-9, R-12, R-15, and R-19. A review of samples from well O-4 indicates that the same relationship can be found there as well. The consistent occurrence of these two subunits beneath the north-central Laboratory site indicates that these are mappable subunits. Borehole geophysical logs from R-7 and from R-19 show that the pumiceous subunit can have greater porosity than the upper fanglomerate-dominated subunit (Appendices F and H in this report, and Broxton et al. 2001, 71253). It is not yet known from direct hydrologic testing whether this difference in porosity translates into higher permeability. However, there is complete clay alteration of the pumiceous subunit in the east at R-9 and R-12, but there is very limited alteration of glass in the overlying fanglomerate. These findings provide a significant paleohydrogeologic indicator of enhanced permeability in the pumiceous subunit at the time of alteration. Where the pumiceous subunit is unaltered, its higher porosity, higher permeability, and higher abundance of reactive high-silica glass justify its treatment as a distinctive subunit.

Figures 10.3-3 and 10.3-4 present two interpretive lines of section through drill hole R-7. These figures illustrate the subdivision of pumice-poor and pumiceous subunits of the Puye Formation as well as the intercalation of Cerros Del Rio lavas within the pumice-poor subunit. The west-east line of section (Figure 10.3-3) connects four drill holes in Los Alamos Canyon. Two of these drill holes (H-19 and O-4) are older and present some problems when integrated with the more recent drill holes, R-7 and R-9. H-19 places Puye Formation fanglomerates between two dacitic Tschicoma lava series and isolates Totavi gravels between Tschicoma lavas at greater depth. There is no information to determine whether the Puye in H-19 is pumice-poor, pumiceous, or both. Because of the lack of such information and the separation of H-19 from drill holes to the east by the Rendija Canyon fault, correlation of the Puye contacts is not shown. In contrast, cuttings are available for O-4 and allow a reassessment of stratigraphy in that drill hole for comparison with R-7 and R-9. The results show a drop in the contact between pumice-poor and pumiceous Puye from O-4 to R-9. The depth to first occurrence of quartzite-bearing river gravels below the pumiceous Puye varies but lies generally between ~5700- and 5900-ft elevation in the northern part of the Laboratory.




*Note:* Stratigraphy for R-9 is from Broxton et al. 2001, 71250.

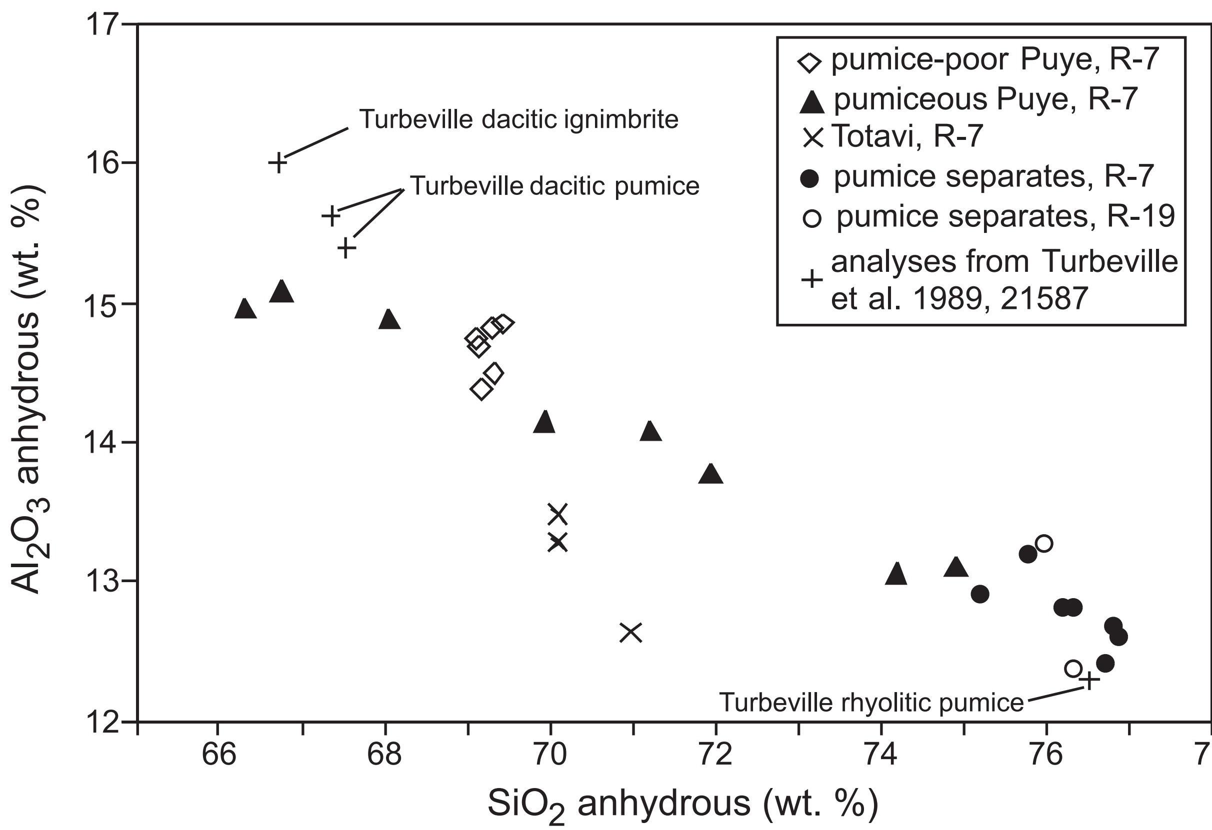
**Figure 10.3-3. Interpretive west-to-east cross section through R-7. (See Figure 1.0-1 for line of section.)**




*Note:* Stratigraphy for R-15 is from Longmire et al. 2001, 70103; stratigraphy for R-19 is from Broxton et al. 2001, 71253.

**Figure 10.3-4. Interpretive northeast-to southwest cross section through R-7. (See Figure 1.0-1 for line of section.)**

The northeast-to-southwest line of section (Figure 10.3-4) combines both outcrop studies (measured section GC-04 of Waresback 1986, 58715) and data from the nearby drill hole G-4, with extension to the southwest through drill holes R-7, R-15, and R-19. From the study by Waresback (1986, 58715) it is clear that the Puye in his field area lacks a lower pumiceous subunit as found beneath the Laboratory. Pumice units and an ignimbrite are present to the north in Waresback's study area, but these units have dacitic compositions unlike the rhyolitic pumices to the south, with the sole exception of one rhyolitic pumice at the *top* of the Puye (data of Turbeville et al., 1989, 21587). These pumice and ignimbrite compositions are compared with Puye data from R-7 in Figure 10.3-5. The lack of such dacitic pumiceous zones or ignimbrite in pumice-poor Puye to the south indicates significant lateral variability in Puye fanglomerates.

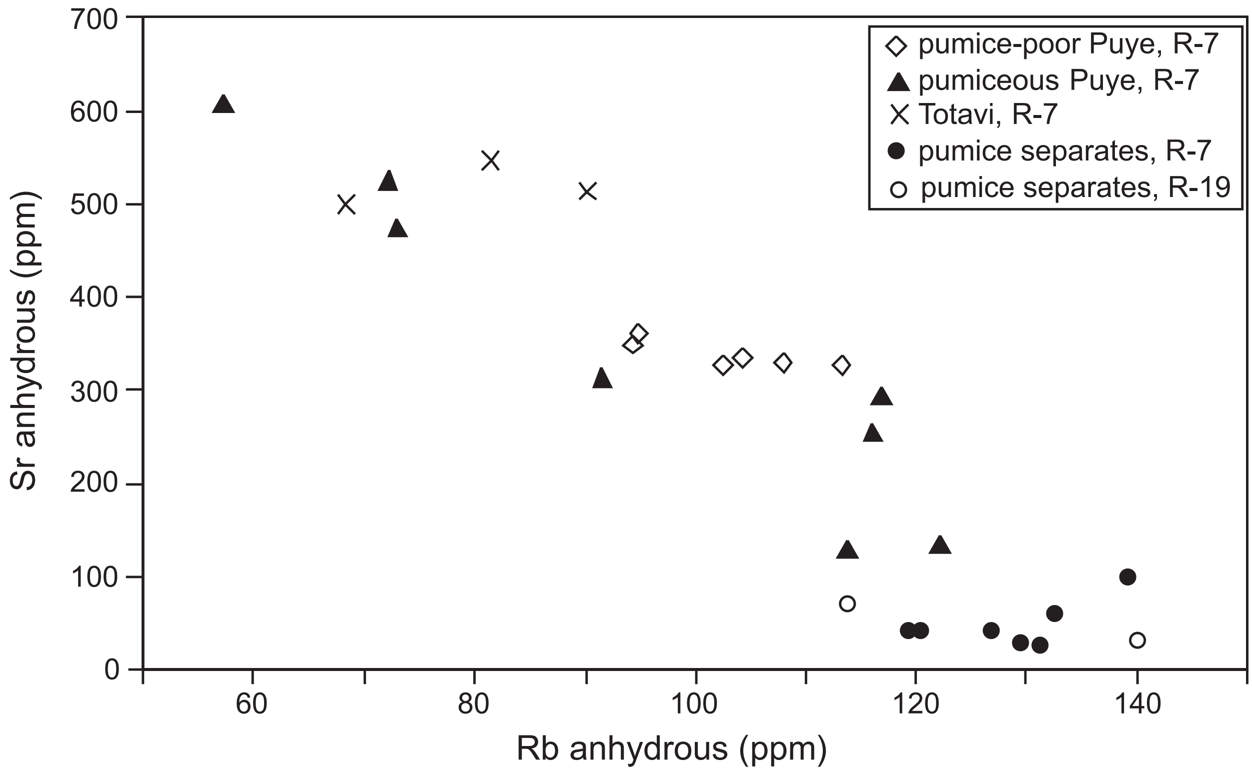



*Note:* All R-7 data are from Tables 10.0-1, 10.0-2, 10.0-3, and 10.0-4. The data are recalculated on a water-free (anhydrous) basis to compensate for the variable effects of glass hydration.

**Figure 10.3-5. Plot of $Al_2O_3$ versus $SiO_2$ for representative Puye sediments at R-7 (diamond, filled triangle, and x symbols); for pumice separates from the pumiceous Puye at R-7 (filled circles); for pumice separates from the pumiceous Puye at R-19 (open circles); and for pumice and ignimbrite samples from an outcrop of the Puye Formation to the north (Turbeville et al. 1989, 21587)**

Analysis of the upper pumice-poor and lower pumiceous Puye at R-19 suggested that at that site, the Rb/Sr ratio rose systematically with depth (Broxton et al. 2001, 71253). This is not the case at R-7, where the pumiceous Puye has Rb or Sr contents both higher and lower than the upper poorly pumiceous Puye

(Figure 10.3-1). In Figure 10.3-6, data for the Puye pumice separates in Table 10.3-3 are compared with similar pumice separates from the pumiceous Puye in R-19 and with the 2- to 4-mm Puye sediment samples from R-7. The trace elements Rb and Sr are used for comparison, as these vary systematically from low Rb/Sr to high Rb/Sr in the transition from mafic to rhyolitic compositions. As noted above and seen in Figure 10.3-1, the pumice-poor Puye varies little in Rb and Sr content, whereas the pumiceous Puye varies from lob Rb/Sr (dacite with little pumice) to high Rb/Sr (dacite with abundant pumice).




*Note:* All R-7 data are from Tables 10.0-1, 10.0-2, 10.0-3, and 10.0-4. The data are recalculated on a water-free (anhydrous) basis to compensate for the variable effects of glass hydration.

**Figure 10.3-6. Plot of Sr versus Rb for representative Puye sediments at R-7 (diamond, filled triangle, and x symbols) and for pumice separates from the pumiceous Puye at R-7 and R-19 (filled and open circles)**

A major feature of the northeast-to-southwest line of section (Figure 10.3-4) is the drop in elevation of both pumice-poor and pumiceous Puye subunits to the southwest. This drop indicates a depositional basin that deepens under the southern part of the Laboratory. The structural setting of this basin is as yet poorly known.

## 11.0 BOREHOLE GEOPHYSICS

A summary of the Schlumberger logging services at R-7 is presented in this section. The complete Schlumberger logging report, a borehole video of R-7, a montage of geophysical logs in the R-7 borehole at total depth, and three interpretive logs are presented as Appendices F, G, H, I, J, and K, respectively, on the CD stored in a Manila envelope attached to the inside back cover of this report.

Schlumberger performed geophysical logging services for Characterization Well R-7 in January 2001 before initial well completion. The log information was acquired in 12.25-in. diameter uncased borehole.

The primary purpose of the geophysical logging was to characterize the geologic/hydrogeologic section intersected by the well, recording information on moisture content, the regional aquifer water table, capacity for flow, and geologic stratigraphy and mineralogy.

The secondary purpose was to evaluate the borehole conditions – geometry, deviation versus depth, and degree of drilling fluid invasion.

These goals were accomplished by measuring, nearly continuously, along the length of the well: (1) total and effective water-filled porosity and pore size distribution, from which an estimate of hydraulic conductivity was made; (2) bulk density and photoelectric effect; (3) bulk electrical resistivity at multiple depths of investigation; (4) spectral natural gamma ray, including potassium, thorium, and uranium concentrations; (5) bedding orientation and geologic texture; (6) borehole diameter; and (7) borehole inclination and azimuth.

### 11.1 Schlumberger Methods

To do this work, Schlumberger used the following tools:

- The Compensated Neutron Tool, model G (CNTG™) to measure volumetric water content beyond the casing, thus evaluating moist/porous zones;
- The Combinable Magnetic Resonance (CMR™) tool to measure the nuclear magnetic resonance response of the formation, evaluating total and effective water-filled porosity of the shallow formation and estimating pore size distribution and hydraulic conductivity;
- The Triple detector Litho-Density (TLD™) tool to measure formation bulk density, photoelectric effect, and borehole diameter using a single-arm caliper to estimate total porosity and characterize lithology;
- The Array Induction Tool, version H, (AITH™) to measure formation electrical resistivity (at five depths) and borehole fluid resistivity, thus evaluating the drilling invasion into the formation, the presence of moist zones far from the borehole wall, and the presence of clay-rich zones;
- The Micro Cylindrically Focused Log (MCFL™) to measure invaded zone high resolution electrical resistivity, thus evaluating invasion into the formation and geologic heterogeneity;
- The Natural Gamma Spectroscopy (NGS™) tool to measure overall and spectral natural gamma ray activity, including potassium, thorium, and uranium concentrations, thus evaluating geology and lithology, particularly the amount of clay;
- The Formation Micro-Imager (FMI™) tool to measure electrical conductivity images of the borehole wall and borehole diameter with a two-axis caliper, thus evaluating geologic bedding and fracturing, including strike and dip of these features, fracture apertures, and rock texture; and
- The General Purpose Inclinometry Tool (GPIT™) to measure borehole deviation and azimuth in open hole, thus evaluating borehole position versus depth and orienting formation images.

- In addition, for the purpose of depth matching the logging runs to each other, calibrated gross gamma ray was recorded with every service except the HNGS.

### 11.2 Schlumberger Results

Preliminary results of these measurements were generated in the logging truck at the time the geophysical services were performed and were documented in field logs. The field results were subsequently reprocessed by Schlumberger: (1) to correct the measurements for borehole environmental conditions; (2) to perform an integrated analysis of the log measurements so that they were coherent; and (3) to combine the logs into a single presentation, enabling integrated interpretation.

Schlumberger concluded that most of the geophysical log measurements from R-7 provided good quality results consistent with each other. The porosity logs were influenced by a few washouts below the well water level that resulted in elevated water-filled porosity and effective porosity measurements in those localized zones. The bulk density log was influenced by significant washouts above the well water level that resulted in erroneously low bulk density and high air-filled porosity in many intervals above the water level (especially between the 440- and 540-ft depths). However, the moisture measurements above the water level, as well as the other measurements throughout the well, were generally unaffected by these large annular voids. The spectral natural gamma ray uranium measurement was negative in certain sections of the borehole (most notably from 350 to 540 ft). The cause of this response is unknown, but it is assumed that the measurement is corrupted in these intervals.

The log results led to the following conclusions:

- The well water level varied considerably over the course of the geophysical logging. The depth of the regional aquifer water table was not clear from the logging results because of high moisture content and possible perched water in the vadose zone. The water table was somewhat arbitrarily designated as 906 ft, based on the different water-sensitive log responses.

- There was relatively high moisture content above the presumed regional aquifer water table, especially below 734 ft, where total and effective water-filled porosity averages about 20% and greater than 5%, respectively. Above 734 ft, total water-filled porosity averages between 10% and 20%, but effective water-filled porosity averages less than 5%.

- There was an indication of the presence of clay throughout the logged section (275 to 1050 ft), with high clay volume fractions (10 to 60%) from 318 to 525 ft, moderate clay volumes (5 to 30%) in the intervals from 525 to 680 ft and from 940 to 1050 ft, and low clay volumes (less than 10%) from 680 to 940 ft.

- There were notable spectral natural gamma ray characteristics in the intervals from 875 to 915 ft (a large uranium peak), from 285 to 325 ft (large thorium and uranium peaks), from 865 ft and 875 ft (step increases in thorium and potassium, respectively, in the up-hole direction), and 730 ft (a step increase in the thorium/potassium ratio in the up-hole direction).

- Bed boundaries between 865 and 1054 ft have predominant strike directions between south and north, with most beds dipping between 230 and 310 degrees (west). More than 90% of these interpreted bed boundaries have dip angles of less than 10 degrees. The electrical resistivity image shows thinly laminated beds of alternating clays and sands through this interval.

### 11.3 LANL Logging

Both video and natural gamma logs were made at R-7 using LANL equipment. Two runs were made with the video camera – one from 0 to 849 ft bgs, and another from 0 to 977 ft bgs. (See Appendix G, Borehole Video of R-7, on CD, back cover.) Video logs provided valuable information on borehole character and the progress of well development. Two runs were also made with the natural gamma tool – one from 0 to 972 ft bgs, and another from 0 to 977 ft bgs. The gamma logs were inconclusive for discriminating stratigraphic units.

## 12.0 HYDROLOGY

Based on observations from wells in the surrounding area, it was predicted that R-7 would encounter two zones of perched saturation as well as the regional zone of saturation. Perched zones were expected in the Guaje Pumice Bed at a depth of 307 to 327 ft and in the Cerros del Rio basalt at a depth of 438 to 646 ft. The regional water table was projected to lie at a depth of 858 ft in the Puye Formation at this location. This section discusses the occurrence and movement of water in the saturated zones encountered in R-7.

### 12.1 Groundwater Occurrence

Perched water was not found where anticipated. That is, the Guaje Pumice Bed was not saturated, and the Cerros del Rio basalt was not present at R-7. It should be noted that the Guaje is saturated at wells LAOI-1.1(A) to the west and LADP3 to the east of R-7.

#### 12.1.1 First Saturation

The driller first detected water near the top of the Puye Formation. The saturation occurred between the depths of 362 and 382 ft bgs. This first water is believed to represent a perched zone in the upper Puye fanglomerate. The water appears to be perched atop a clay-rich zone extending from a depth of 382 to 397 ft. Geophysical logs indicate that the top of the perched saturation is at a depth of 373 ft bgs. It is targeted by screen #1, with openings positioned 363 to 379 ft bgs.

#### 12.1.2 Other Saturation in Vadose Zone

Video logging showed the borehole wall to be wet over most of its length, but not very productive. Borehole geophysics indicates abundant free water and highly porous rocks in this interval of the pumiceous strata assigned to the Puye Formation. Porosity does not guarantee permeability, especially in the case of pumice. Nonetheless, screen #2 was placed with openings in the interval 730 to 746 ft bgs.

#### 12.1.3 Deep Saturation

Saturation believed to be associated with the regional aquifer was encountered somewhat deeper in the pumiceous Puye strata. The water-level associated with this saturation was first measured to be 879 ft bgs and, some time later, to be 899 ft bgs. In the initial round of video logging, the regional water table was encountered at a depth of 848 ft, but a later round showed it to be at a depth of 902.8 ft. This final static level is 45 ft deeper than the projected water-table depth of 858 ft. Access to the regional zone of saturation is provided by a single screen (#3), placed with openings between 895 and 937 ft bgs.

### 12.2 Groundwater Movement

Groundwater movement is usually defined in terms of both a direction and a rate. Although data for evaluating horizontal flow direction is not provided by a single well, vertical direction of movement can be determined by analysis of head distribution along the borehole. Although true head measurements are not available because of long intervals of open hole, available measurements of water level versus borehole depth during drilling suggest that the direction of vertical gradient is downward at R-7. This finding is consistent with the conceptual hydrogeologic model for the Pajarito Plateau in general and this wet canyon in particular.

A potential rate of groundwater movement would have been suggested by hydraulic properties of the saturated materials. However, such properties of materials penetrated by R-7 are unknown. No hydrologic testing of the upper two screens was possible because they were not productive, and testing was inappropriate for the bottom screen (#3) because it straddles the water table.

## 13.0 GEOCHEMISTRY OF SAMPLED WATERS

Sampled waters at R-7 include groundwater collected from a perched zone and from the regional aquifer. Screen #1 was situated to collect groundwater that accumulates in this perched zone. No groundwater samples were collected from the interval targeted by screen #2 because of insufficient sample volume. Samples of regional groundwater were obtained from screen #3. This section focuses on chemical data obtained from the perched zone and the regional aquifer.

Two groundwater samples (perched zone and regional aquifer) were collected from the borehole during drilling and were analyzed for a suite of constituents. The samples were collected primarily to determine whether potential contaminants had been introduced from upper horizons into the regional aquifer during drilling operations. Potential contaminants of concern at R-7 include strontium-90, tritium, uranium, perchlorate, molybdenum, americium-241, plutonium-238, and plutonium-239,240 released from former TA-1, TA-2, and TA-41 in upper Los Alamos Canyon. Concentrations of all analytes at R-7 are < maximum contaminant levels (MCLs), action levels, and health-advisory levels.

The two borehole samples contain some drilling fluids and thus are not representative of purely native groundwater. Groundwater samples collected were obtained during active drilling while EZ-MUD® and other additives were being used for lubricity. These additives can affect groundwater chemistry, and the R-7 water compositions reported here should be evaluated in light of this complexity. Concentrations of iron, manganese, and sulfate are all altered in the presence of EZ-MUD®. However, other constituents are not impacted by the presence of the additives used and provide useful information, including the presence or absence of mobile contaminants (tritium, chloride, and perchlorate). These data provide baseline groundwater compositions as present during drilling, against which groundwater analyses from the completed and developed well can be compared.

### 13.1 Methods

Groundwater samples analyzed for inorganic and organic chemicals and radionuclides were collected using a stainless-steel bailer at 362 ft (perched zone) and at 903 ft (regional aquifer) in R-7. Temperature, turbidity, pH, and specific conductance were not determined on-site due to sample matrix. Both filtered (metals, trace elements, and major cations and anions) and non-filtered (stable isotopes of hydrogen and oxygen and radionuclides) samples were collected for chemical and radiochemical analyses. Aliquots of the samples were filtered through a 0.45-µm Gelman filter. Samples were acidified with analytical-grade $HNO_3$ to a pH of 2.0 or less for metal and major-ion analyses. All groundwater samples collected were stored at 4°C until they were analyzed. Alkalinity was determined in the laboratory (LANL and Paragon Analytics, Inc.) using standard titration techniques, which may not approximate field conditions because of sample degassing. Water samples were also preserved with $HNO_3$ prior to radiometric/radiochemical analyses (excluding tritium).

Groundwater samples were analyzed using techniques specified in the EPA SW-846 manual. Analytical methods including ion chromatography (IC) for bromide, chloride, fluoride, nitrate plus nitrite, perchlorate, phosphate, and sulfate were used at the Hydrology, Geochemistry and Geology Group (EES-6), General Engineering Laboratories (GEL), and Paragon Analytics, Inc. The ion-selective electrode (ISE) method was used for ammonium analysis, and the cold-vapor atomic absorption (CVAA) method was used for mercury analysis at both laboratories. Inductively coupled (argon) plasma mass spectrometry (ICPMS) was used for analyses of aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, potassium, selenium, silver, strontium, thallium, uranium, vanadium, and zinc at EES-6. Inductively coupled (argon) plasma optical emission spectroscopy (ICPOES) was the analytical method for aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, silver, sodium, thallium, vanadium, and zinc at Paragon Analytics, Inc. Sodium and silicon were analyzed by ICPOES at EES-6. Antimony, beryllium, cadmium, lead, and thallium were also analyzed at GEL using ICPMS.

Radionuclide activity in groundwater was determined: by direct counting and electrolytic enrichment for low-level tritium; by alpha spectrometry for americium, plutonium, and uranium isotopes; by gas proportional counting for strontium-90; and by gamma spectrometry for cesium-137 and other gamma-emitting isotopes. Contract laboratories performing this work were Paragon Analytics, Inc. (radionuclides) and the University of Miami (low-level tritium).

High explosive compounds and degradation products were analyzed by high-pressure liquid chromatography (HPLC) using EPA method 8330. These chemicals were analyzed on nonfiltered and nonacidified groundwater samples collected in 1-L glass amber bottles.

Stable isotopes of oxygen (oxygen-18 and oxygen-16, $\delta^{18}O$) and hydrogen (hydrogen [protium] and deuterium, $\delta D$) were analyzed by Geochron Laboratories (Cambridge, Massachusetts) using isotope-ratio mass spectrometry (IRMS). Laboratory blanks were collected and analyzed in accordance with EPA and Laboratory procedures. The precision limits (analytical error) for major ions and trace elements were generally ±10%.

### 13.2 Geochemistry of Groundwater from Perched Zone

Activity of tritium in a groundwater sample from the Puye Formation at 362 ft is 6.5 pCi/L (Table 13.2-1a). This fact suggests that minimal recharge to the perched zone, which may contain Laboratory-derived effluents, may have occurred since the 1940s. The dominant potential sources of tritium are inactive Laboratory discharges at TA-2 upgradient of R-7 and atmospheric (worldwide) fallout from weapons testing. Activities of other radionuclides, including cesium-137, europium-152, plutonium-238, plutonium-239,240, and americium-241, were less than instrument detection limits (DLs) for groundwater samples collected from the perched zone at R-7. Strontium-90 was detected, however, in the perched zone (solid sample) at an activity of 0.65 ± 0.155 ($1\sigma$) pCi/g with a minimum detectable activity (MDA) of 0.44 pCi/g (Table 13.2-1a). This value is very close to the instrument MDA, and the activity should be considered as an estimated value. Strontium-90 adsorbs onto clay minerals present in the Bandelier Tuff and overlying alluvium containing solid organic matter (Longmire et al. 1996, 54168). Isotopes of natural uranium were detected in both groundwater and sediment samples collected within the perched zone at R-7. Activities of uranium-238 are 26.2 pCi/L (78.4 µg/L) in the nonfiltered groundwater sample collected from the perched zone. This activity does not compare well to the 0.0014 mg/L using ICPMS. This discrepancy could be the result of complete digestion of the turbid sample, containing clay minerals including smectite and kaolinite, prior to analysis using alpha spectrometry. Naturally occurring uranium may have desorbed from the dissolving clay minerals during sample acidification.

**Table 13.2-1a**
**Radionuclide Activities in Perched Zone and Regional Aquifer at R-7**
**(Nonfiltered Samples)**

| **Depth (ft)** | **362** | **902** |
|---|---|---|
| **Geologic Unit** | **Puye Formation** | **Puye Formation** |
| **Aquifer** | **Perched** | **Regional** |
| **Date Sampled** | **01/06/01** | **01/10/01** |
| Tritium (pCi/L) | 6.5 | 0.26, U |
| Am-241 (pCi/g) | 0.013, U | 0.01, U |
| Am-241 (pCi/L) | 0.038, U | 0.041, U |
| Cs-137 (pCi/g) | 0.023, U | — |
| Cs-137 (pCi/L) | -0.9, U | 0.1, U |
| Co-60 (pCi/g) | 0.027, U | — |
| Co-60 (pCi/L) | -0.2, U | -1.1, U |
| Eu-152 (pCi/g) | 0.0, U | — |
| Eu-152 (pCi/L) | -0.5, U | 1.7, U |
| Pu-238 (pCi/g) | -0.0046, U | -0.001, U |
| Pu-238 (pCi/L) | 0.005, U | -0.004, U |
| Pu-239,240 (pCi/g) | -0.0009, U | 0.0014, U |
| Pu-239,240 (pCi/L) | 0.044, U | -0.001, U |
| Sr-90 (pCi/g) | 0.65 | 0.38, U |
| Sr-90 (pCi/L) | 0.07, U | 0.02, U |
| U-234 (pCi/g) | 1.62 | 0.95 |
| U-234 (pCi/L) | 31.2 | 1.48 |
| U-235 (pCi/g) | 0.082 | 0.078 |
| U-235 (pCi/L) | 1.36 | 0.075 |
| U-238 (pCi/g) | 1.88 | 1.22 |
| U-238 (pCi/L) | 26.2 | 0.90 |
| $\delta D$ (‰) | -72 | -77 |
| $\delta^{18}O$ (‰) | -10.8 | -11 |

*Note:* U means not detected; a dash in the table means “not analyzed”; and ‰ means permil.

The borehole groundwater sample collected from within the perched zone at R-7 is characterized by a sodium-calcium-bicarbonate ionic composition (Table 13.2-1b). Concentrations of sulfate and chloride are <5 mg/L, and concentrations of nitrate plus nitrite (as nitrogen) are <0.5 mg/L. Concentrations of dissolved iron and manganese are above instrument DLs, suggesting mildly reducing conditions with respect to these two solutes. Under relatively reducing conditions, iron(III) and manganese(IV) solids are characterized by increasing solubility (Langmuir 1997, 56037). The concentration of dissolved uranium is 0.0014 mg/L within the perched saturated zone at R-7 (Table 13.2-1b).

**Table 13.2-1b**
**Hydrochemistry of Perched Zone Samples at R-7**

| **Depth (ft)** | **362** | **362** |
|---|---|---|
| **Geologic Unit** | **Puye Formation** | **Puye Formation** |
| **Aquifer** | **Perched** | **Perched** |
| **Date Sampled** | **01/06/01** | **01/06/01** |
| **Laboratory** | **Paragon/GEL**[a] | **EES-6** |
| Alkalinity (mg $CaCO_3$/L) | 120 | 58.2 |
| Al (mg/L) | 3.4 | 1.11 |
| $NH_4$ (as N) (mg/L) | 3.70 | 1.27 |
| Sb (mg/L) | 0.00546 | 0.0094 |
| As (mg/L) | 0.0025, U | — |
| Ba (mg/L) | 0.034 | 0.017 |
| Be (mg/L) | 0.000055, U | <0.001, U |
| $HCO_3$ (mg/L) | 146 | 71.0 |
| B (mg/L) | 0.010 | 0.014 |
| Br (mg/L) | 0.20, U | <0.02, U |
| Cd (mg/L) | 0.000889 | <0.001, U |
| Ca (mg/L) | 7.10 | 7.56 |
| Cl (mg/L) | 5.20 | 4.57 |
| Cr (total) (mg/L) | 0.0024 | 0.001 |
| Co (mg/L) | 0.005 | 0.004 |
| Cu (mg/L) | 0.0082 | 0.0063 |
| F (mg/L) | 0.65 | 0.23 |
| Fe (mg/L) | 2.2 | 0.48 |
| Pb (mg/L) | 0.000543 | <0.001, U |
| Mg(mg/L) | 2.5 | 2.22 |
| Mn (mg/L) | 0.140 | 0.11 |
| Mo (mg/L) | 0.016 | 0.015 |
| Hg (mg/L) | 0.000016, U | <0.00005, U |
| Ni (mg/L) | 0.0068 | 0.0041 |
| $NO_3$ + $NO_2$ (as N) (mg/L) | 0.10, U | 0.41 |
| $C_2O_4$ (oxalate)(mg/L) | 0.190, U | <0.02, U |
| $ClO_4$ (mg/L) | 0.000958, U | <0.002, U |
| $PO_4$ (as P) (mg/L) | 0.050, U | <0.02, U |

**Table 13.2-1b (continued)**

| Depth (ft) | 362 | 362 |
|---|---|---|
| **Geologic Unit** | **Puye Formation** | **Puye Formation** |
| **Aquifer** | **Perched** | **Perched** |
| **Date Sampled** | **01/06/01** | **01/06/01** |
| **Laboratory** | **Paragon/GEL[a]** | **EES-6** |
| K (mg/L) | 6.80 | 6.61 |
| Se (mg/L) | 0.0025, U | <0.001, U |
| $SiO_2$ (mg/L) | — | 51.8 |
| Ag (mg/L) | 0.00078 | <0.001, U |
| Na (mg/L) | 14.0 | 17.3 |
| Sr (mg/L) | 0.052 | 0.045 |
| $SO_4$ (mg/L) | 3.30 | 3.47 |
| Tl (mg/L) | 0.000077, U | <0.001, U |
| TKN (mg/L) | 6.00 | — |
| U (mg/L) | 0.00116 | 0.0014 |
| V (mg/L) | 0.002 | 0.001 |
| Zn (mg/L) | 0.056 | 0.050 |

*Note:* U means not detected, and a dash in the table means “not analyzed.”
[a] GEL used ICPMS to analyze for Sb, Be, Cd, Pb, Tl, and U.

Concentrations of dissolved beryllium, bromide, cadmium, lead, mercury, oxalate, perchlorate, phosphate, selenium, silver, and thallium are less than instrument DLs (IC, ICPOES, and ICPMS) in the groundwater sample from the perched zone at R-7. Trace solutes including aluminum, antimony, boron, cobalt, copper, molybdenum, nickel, strontium, vanadium, and zinc, however, were detected in the groundwater sample collected at a depth of 362 ft (Table 13.2-1b). These solutes are naturally occurring in groundwater because of adsorption/desorption processes involving aquifer material containing clay minerals and manganese and iron (oxy)hydroxides (Langmuir 1997, 56037).

HE compounds and associated degradation products were not detected in groundwater samples within the perched zone during drilling at R-7.

Analytical results reported by EES-6 compare well with those provided by Paragon Analytics, Inc., and GEL (Table 13.2-1b). Exceptions include alkalinity (bicarbonate), aluminum, ammonium, barium, iron, and nitrate plus nitrite. Organic acids present in EZ-MUD® contribute to increasing alkalinity, and, over time, these acids accumulate because of the breakdown of the EZ-MUD®. Concentration differences for barium and nitrate plus nitrite reported by EES-6 and Paragon Analytics, Inc., are within a factor of four at values <1 mg/L. Aluminum and ammonium concentrations reported by both laboratories vary within a factor of three in the low mg/L range. EES-6 uses ICPMS for aluminum and barium analyses, whereas Paragon Analytics, Inc., uses ICPOES for the same analytes. ICPMS is a more sensitive and accurate analytical method with less matrix interference compared to ICPOES.

Ratios of $\delta D$ and $\delta^{18}O$ are -72 and -10.8 permil, respectively, suggesting that the borehole water in the perched zone is derived from a meteoric (atmospheric) source west of the Laboratory (small activities of tritium) and evaporation has not taken place to a significant extent. The equation for the Jemez Mountains meteoric line (JMML) (Blake et al. 1995, 49931) is given by the following expression:

$$\delta D = 8\delta^{18}O + 12. \qquad \textbf{Equation 13-1}$$

The measured values for $\delta D$ and $\delta^{18}O$ plot slightly above the JMML with analytical errors for $\delta D$ and $\delta^{18}O$ of ± 4 and 0.2 permil, respectively.

### 13.3 Geochemistry of Groundwater from the Regional Aquifer

Activities of tritium in regional-aquifer samples from the Puye Formation at 903 ft are 0.26 pCi/L (U value) (Table 13.3-1). This finding suggests that recharge to this part of the aquifer has not occurred since the 1940s. Activities of other radionuclides, including strontium-90, cesium-137, europium-152, plutonium-238, plutonium-239,240, and americium-241, were less than instrument detection limits in the groundwater sample collected from the regional aquifer at R-7. Isotopes of natural uranium were detected at activities <2 pCi/L in groundwater samples collected within the regional aquifer at R-7.

Borehole groundwater samples collected from within the regional aquifer in R-7 are characterized by a calcium-sodium-bicarbonate ionic composition (Table 13.3-1). Concentrations of sulfate and chloride are less than 2 mg/L, and the concentrations of nitrate plus nitrite (as nitrogen) are less than 0.2 mg/L. Concentrations of dissolved iron and manganese are just above instrument DLs. This finding suggests overall oxidizing conditions, during drilling, with respect to these two solutes. Under relatively oxidizing conditions, iron and manganese precipitate from solution, forming moderately insoluble oxide and oxyhydroxide phases (Langmuir 1997, 56037). The concentration of natural uranium is 0.0021 mg/L within the regional aquifer at R-7 (Table 13.3-1).

Concentrations of dissolved bromide, mercury, oxalate, phosphate, selenium, and thallium are less than DLs (IC, ICPOES, and ICPMS) in the groundwater sample collected from the regional aquifer at R-7. Trace solutes including aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, cobalt, copper, lead, molybdenum, nickel, perchlorate, strontium, vanadium, and zinc were detected in the regional groundwater sample, as analyzed by EES-6, Paragon Analytics, Inc., or GEL (Table 13.3-1). The concentration of perchlorate (0.00221 mg/L) reported for the groundwater sample collected in the regional aquifer is below the instrument (IC) reporting limit (RL) of 0.0040 mg/L, and this value should be considered as an estimated (J) value. There is a high uncertainty with the presence of perchlorate at the observed concentration at borehole R-7. Additional sampling for perchlorate has been conducted at R-7 with concentrations less than detection.

HE compounds and associated degradation products were not detected in groundwater samples within the regional aquifer during drilling at R-7.

Analytical results reported by EES-6 also are in good agreement with those provided by Paragon Analytics, Inc., and GEL (Table 13.3-1). Exceptions include aluminum, chromium, iron, molybdenum, and vanadium. Concentration differences for these analytes reported by EES-6 and Paragon Analytics, Inc., are within a factor of four at values much less than 1 mg/L. EES-6 uses ICPMS for aluminum, iron, molybdenum, and vanadium, whereas Paragon Analytics, Inc., uses ICPOES, a less sensitive method.

Based on the above analytical results for the R-7 borehole water samples collected with the regional aquifer, it appears that contamination containing mobile solutes, including tritium and chloride, is not present at this well site. Additional characterization sampling is planned at the completed R-7 well.

**Table 13.3-1**
**Hydrochemistry of Regional Groundwater from the Puye Formation (902 ft) at R-7**

| Date Sampled | 01/10/01 | 01/10/01 |
|---|---|---|
| **Laboratory** | **Paragon/GEL[a]** | **EES-6** |
| Alkalinity (mg $CaCO_3$/L) | 72.0 | 68.4 |
| Al (mg/L) | 0.190 | 0.77 |
| $NH_4$ (as N) (mg/L) | 0.50, U | 0.19 |
| Sb (mg/L) | 0.00089, U | 0.0004 |
| As (mg/L) | 0.0032, U | 0.0005 |
| Ba (mg/L) | 0.030 | 0.034 |
| Be (mg/L) | 0.000081 | <0.001, U |
| $HCO_3$ (mg/L) | 87.8 | 83.5 |
| B (mg/L) | 0.011 | 0.015 |
| Br (mg/L) | 0.20, U | <0.01, U |
| Cd (mg/L) | 0.000176 | <0.001, U |
| Ca (mg/L) | 12.0 | 12.7 |
| Cl (mg/L) | 2.20 | 1.47 |
| Cr (total) (mg/L) | 0.00095, U | 0.002 |
| Co (mg/L) | 0.0017, U | 0.002 |
| Cu (mg/L) | 0.0015 | 0.0020 |
| F (mg/L) | 0.29 | 0.29 |
| Fe (mg/L) | 0.28 | 0.65 |
| Pb (mg/L) | 0.00391 | 0.0045 |
| Mg(mg/L) | 3.90 | 4.25 |
| Mn (mg/L) | 0.062 | 0.067 |
| Mo (mg/L) | 0.0045, U | 0.014 |
| Hg (mg/L) | 0.000016, U | <0.00005, U |
| Ni (mg/L) | 0.0031, U | 0.0022 |
| $NO_3$ + $NO_2$ (as N) (mg/L) | 0.16 | 0.17 |
| $C_2O_4$ (oxalate)(mg/L) | 0.190, U | <0.02, U |
| $ClO_4$ (mg/L) | 0.00221 | <0.002, U |
| $PO_4$ (as P) (mg/L) | 0.52, U | <0.02, U |
| K (mg/L) | 2.20 | 2.15 |
| Se (mg/L) | 0.0025, U | <0.001, U |
| $SiO_2$ (mg/L) | — | 80.9 |
| Ag (mg/L) | 0.00062 | <0.001, U |
| Na (mg/L) | 9.10 | 10.5 |
| Sr (mg/L) | 0.061 | 0.060 |
| $SO_4$ (mg/L) | 1.90 | 1.81 |
| Tl (mg/L) | 0.000077, U | <0.001, U |
| TKN (mg/L) | 0.78 | — |
| U (mg/L) | — | 0.0021 |
| V (mg/L) | 0.0025 | 0.005 |
| Zn (mg/L) | 0.0069, U | 0.006 |

*Note:* U means not detected, and a dash in the table means “not analyzed.”
[a] GEL used ICPMS to analyze for Sb, Be, Cd, Pb, and Tl.

Ratios of $\delta D$ and $\delta^{18}O$ are -77 and -11 permil, respectively, suggesting that the borehole water in the regional aquifer is derived from a meteoric (atmospheric) source, and evaporation has not taken place to a significant extent. The measured values for $\delta D$ and $\delta^{18}O$ plot slightly below the JMML (Equation 13-1) with analytical errors for $\delta D$ and $\delta^{18}O$ of ±4 and 0.2 permil, respectively. Very similar stable-isotope ratios measured in the perched zone and regional aquifer suggest either that mixing of waters has occurred within the open borehole at R-7 or that the waters have similar recharge sources.

## 14.0 IMPLICATIONS OF R-7 FOR THE CONCEPTUAL MODELS OF GEOLOGY, HYDROLOGY, AND GEOCHEMISTRY

Drill hole R-7 has provided geologic samples that are pivotal in clarifying the distinction between two mappable subunits of the Puye Formation beneath the Laboratory—an upper pumice-poor subunit and a lower pumiceous subunit. The lower pumiceous subunit is a new addition to Puye stratigraphy, apparently absent to the north (Turbeville et al. 1989, 21587) and along the eastern edge of the Laboratory (Dethier, 1997, 49843) where studies of the Puye in outcrop are possible. The pumiceous Puye subunit at R-7 is thick and relatively unaltered, unlike the thinner and completely clay-altered occurrences of this subunit to the east at R-9 and R-12. The implication of this highly variable alteration within the pumiceous Puye is that clay alteration will eventually have to be mapped within this subunit of the 3-D Geologic Model, for this alteration significantly affects both porosity and permeability.

Screen #2 straddles the boundary between pumice-poor and pumiceous Puye subunits. A screen was placed at this horizon because of indications of an increase in pore saturation at this contact, based on combined magnetic resonance (CMR) borehole logging. As with screen #1, if water can be collected and analyzed from this screen, results can be compared with those for water from the zone of regional saturation to determine whether distinct groundwater compositions should be used in modeling reactive transport in supraregional versus regional hydrologic systems.

Screen #3 spans the regional water table. This screen includes both dacite-rich and rhyolitic pumice-rich zones of the pumiceous Puye. At R-19, screens #6 and #7 are also located in the pumiceous Puye subunit. Studies of hydrologic testing results and of quarterly groundwater sampling results from this suite of screens, compared with screens in the Puye fanglomerates at R-19 and other drill holes, can be used to determine whether the pumiceous and pumice-poor subunits need to be treated separately in flow and transport modeling.

Geochemical data were obtained for waters collected near the ultimate positions of screen #1 (362-ft depth) and screen #2 (902-ft depth). With the exception of a small amount of tritium in the perched water, no evidence of any Laboratory contamination was detected. Absence of tritium in water associated with the regional aquifer indicates little or no influx of young water to that depth. Quarterly sampling will provide additional data on groundwater chemistry.

## 15.0 ACKNOWLEDGMENTS

Numerous organizations and individuals contributed to the installation and characterization of R-7. This work involved various management efforts as well as site and laboratory activities.

### 15.1 Management

Work was done with the cooperation of M. Salazar, facility manager for TA- 53.

The Groundwater Integration Team, led by C. Nylander, was involved in the planning of R-7.

J. McCann managed operations as leader of ER's Groundwater Investigations Focus Area.

T. Ball provided ER contract oversight, and S. Pearson provided ER field oversight. G. Turner provided Department of Energy (DOE) oversight during the installation of the well. J. Young (Hazardous Waste Bureau) and M. Dale (DOE Oversight Bureau) provided New Mexico Environment Department (NMED) oversight of operations.

S. Hagelberg, J. Valdez, and A. Garcia provided sample management support. B. Hardesty provided data-management support. M. Clevenger curated borehole material.

C. Schaller was editor for this document, and P. Maestas was compositor.

R. Bohn, R. Enz, A. Groffman, and D. Hickmott reviewed the document.

### 15.2 Site and Laboratory Activities

SG Western constructed the drill pad.

Stewart Brothers Drilling Company did the drilling for Phase I. The driller was S. Johnson.

Dynatec Drilling, Incorporated, did the drilling for Phase II. Drillers were L. Thoren, D. Wilson, G. Woodward, R. Brown, C. Howe and S. Devers.

J. Skalski, L. Martinez, and J. Duran provided technical and field support of drilling. M. Everett, A. Crowder, R. Lawrence, P. Schuh, J. Jordan, J. McDonald, D. Frank, and C. Schultz provided field support for geologic logging, water sampling, well completion, and well development.

D. Counce performed screening analyses of groundwater samples.

A. Crowder and M. Everett conducted geophysical and video logging with LANL's equipment.

H. Patillo was site safety officer.

M. Dale collected sample splits from groundwater zones for NMED.

D. Larssen installed the Westbay sampling system.

R. Bohn, R. Evans, and M. Shepard were responsible for waste management.

Keers Environmental did the site restoration.

## 16.0 REFERENCES

Blake, W. D., F. Goff, A. I. Adams, and D. Counce, May 1995. "Environmental Geochemistry for Surface and Subsurface Waters in the Pajarito Plateau and Outlying Areas, New Mexico," Los Alamos National Laboratory Report LA-12912-MS, Los Alamos, New Mexico. (Blake et al. 1995, 49931)

Broxton D., R. Gilkeson, P. Longmire, J. Marin, R. Warren, D. Vaniman, A. Crowder, B. Newman, B. Lowry, D. Rogers, W. Stone, S. McLin, G. WoldeGabriel, D. Daymon, and D. Wyckoff, May 2001. "Characterization Well R-9 Completion Report," Los Alamos National Laboratory Report LA-13742-MS, Los Alamos, New Mexico. (Broxton et al. 2001, 71250).

Broxton, D., D. Vaniman, W. Stone, S. McLin, J, Marin, R. Koch, R. Warren, P. Longmire, D. Rogers, and N. Tapia, May 2001. “Characterization Well R-19 Completion Report,” Los Alamos National Laboratory Report LA-13823-MS, Los Alamos, New Mexico. (Broxton et al. 2001, 71253).

Dethier, D. P., 1997. “Geology of White Rock Quadrangle, Los Alamos and Santa Fe Counties, New Mexico," Geologic Map 73, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico, scale 1:24,000. (Dethier 1997, 49843).

Langmuir, D., 1997. Aqueous Environmental Geochemistry, Prentice-Hall, Inc., Upper Saddle River, New Jersey. (Langmuir 1997, 56037)

LANL (Los Alamos National Laboratory), May 22, 1998. “Hydrogeologic Workplan,” rev. 1.0, Los Alamos, New Mexico. (LANL 1998, 59599)

Longmire, P. A., S. Kung, J. M. Boak, A. I. Adams, F. Caporuscio, and R. N. Gray, 1996. “Aqueous Geochemistry of Upper Los Alamos Canyon, Los Alamos, New Mexico,” in New Mexico Geological Society Guidebook, 47th Field Conference, Jemez Mountains Region, New Mexico, pp. 473–480. (Longmire et al. 1996, 54168)

Longmire P., D. Broxton, W. Stone, B. Newman, R. Gilkeson, J. Marin, D. Vaniman, D. Counce, D. Rogers, R. Hull, S. McLin, and R. Warren, May 2001. “Characterization Well R-15 Completion Report,” Los Alamos National Laboratory Report LA-13749-MS, Los Alamos, New Mexico. (Longmire et al. 2001, 70103).

Turbeville, B. N., D. B. Waresback, and S. Self, 1989. “Lava-Dome Growth and Explosive Volcanism in the Jemez Mountains, New Mexico: Evidence from the Plio-Pleistocene Puye Alluvial Fan,” Jour. Volcanology and Geothermal Res. 36, 267–291. (Turbeville et al. 1989, 21587)

Waresback, D. B., August 1986. “The Puye Formation, New Mexico: Analysis of a Continental, Rift-Filling, Volcaniclastic Alluvial-Fan Sequence,” Master of Science in Geology thesis, University of Texas, Arlington, Texas. (Waresback 1986, 58715).

# NOTES

# NOTES

# NOTES

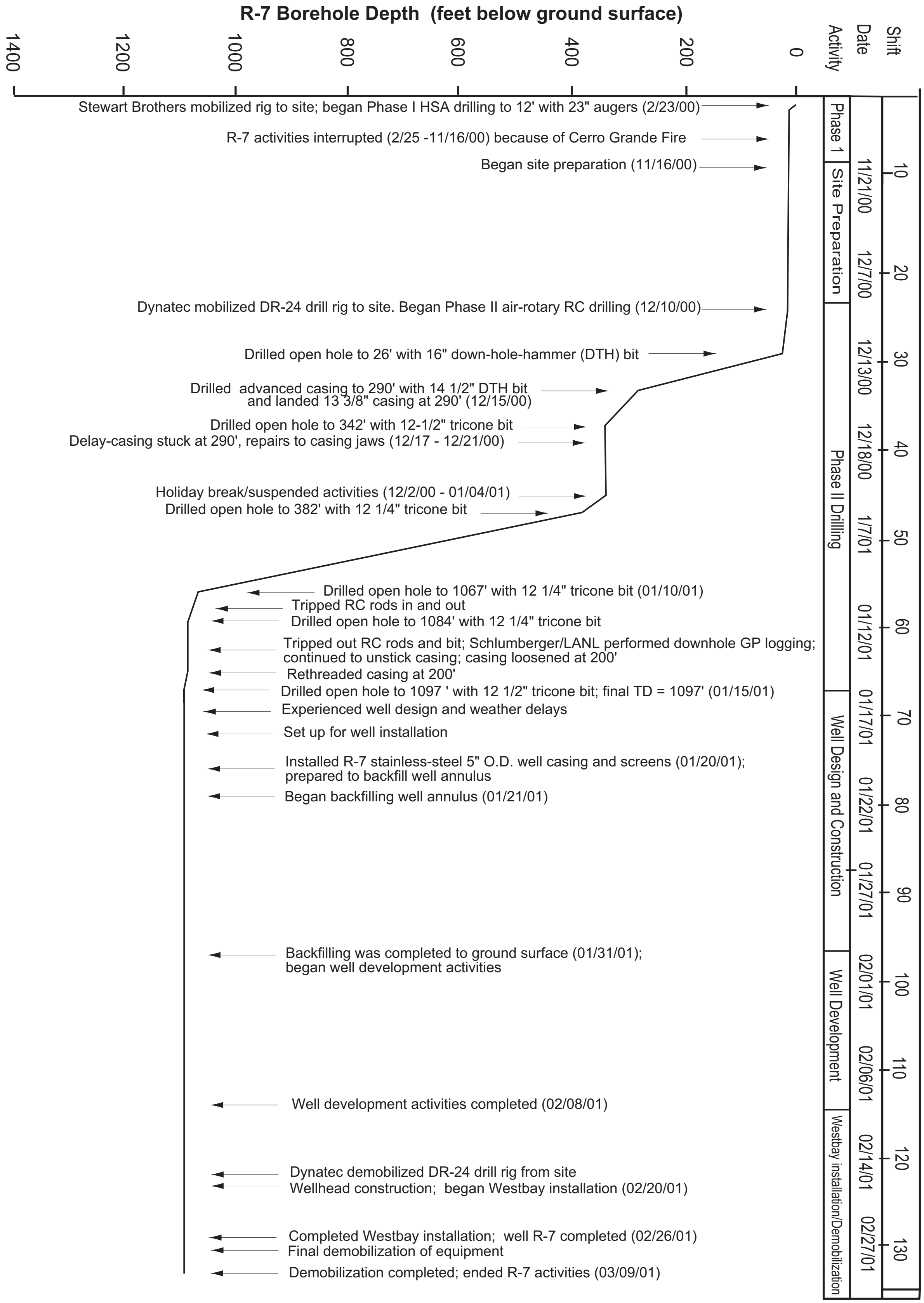
# NOTES

## NOTES

# Appendix A

*Diagram of Site Activities Related to Progress*

# R-7 Operations Chronology Graph



# Appendix B

*Borehole Log*

Note: American Society for Testing Materials (ASTM) standards were used in describing the texture of drill chip samples for sedimentary rocks such as the Puye Fanglomerate. ASTM method D 2488-90 incorporates the Unified Soil Classification System (USCS) as a standard for field examination and description of soils. The following is a glossary of standard USCS symbols used in the R-7 lith log.

SW Well graded sand

SP Poorly graded sand

GW Well graded gravel

GP Poorly graded gravel

SM Silty sand

SC Clayey sand

GC Clayey gravel

GM Silty gravel

**REFERENCE**

ASTM D 2488-90. Standard Practice and Identification of Soils (Visual-Manual Procedure)

Note: Cuttings were collected at nominal 5-ft intervals and divided into three sample splits: (1) unsieved bulk, or whole rock (WR); (2) >10 sieved fraction (No. 10 sieve equivalent to 2.00 mm); and (3) >35 sieved fraction (No. 35 sieve equivalent to 0.50 mm).

Note: The term "percent," as used in the descriptions on pages B-2 through B-14, refers to percent by volume.

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BOREHOLE LOG

| | | |
|---|---|---|
| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 1 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | | SAMPLING EQ/METHOD: Cuttings |
| GROUND ELEVATION: 6779.2 ft | | TOTAL DEPTH = 1097 ft bgs |
| DRILLER: Thoren, Wilson, Brown | | GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) |
|---|---|
| 0 | |
| 5 | 6775 |
| 10 | 6770 |
| 15 | 6765 |
| 20 | 6760 |
| 25 | 6755 |
| 30 | 6750 |
| 35 | 6745 |
| 40 | 6740 |
| 45 | 6735 |
| 50 | 6730 |
| 55 | 6725 |
| 60 | 6720 |
| 65 | 6715 |
| 70 | 6710 |
| 75 | 6705 |
| 80 | 6700 |
| 85 | 6695 |

| Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|
| No core attempted | | 0–85 ft | | No samples collected | ALLUVIUM: (0-25 ft) Unconsolidated sediments, silty sandy gravel (GM), light brownish gray (5YR 6/1). Poorly sorted, angular to subrounded, fine-grained sand to coarse gravel (up to 3 cm), grains consist of quartz, intermediate composition volcanics, and sanidine, pumice fragments increase downward in the interval. Cobbles and boulders of intermediate composition volcanics were encountered in the 10-15-ft interval. Descriptions for the interval 0-50 ft are of drill cuttings produced during Phase 1 HSA drilling. | | Qal |
| | | | | | OTOWI MEMBER, BANDELIER TUFF: (25-50 ft) Volcanic tuff, Moderate yellowish brown (10YR 5/4). Vitric, nonwelded, 10-15% felsic phenocrysts, 5% lithics. Percent of crystals increased in the 45-50' interval. Pumice fragments are orange to light gray, up to 45 mm. Descriptions for the interval 50-1097 ft are of drill cuttings collected during Phase 2 reverse-circulation rotary drilling. | | Qbo |
| | | | | | OTOWI MEMBER, BANDELIER TUFF: (50-80 ft) Volcanic tuff, medium yellow brown (10YR 5/4). Greater than 35 mesh: (i.e., plus No. 35 mesh sieved fraction): 75-80% quartz & sanidine crystals, 10-20% volcanic lithics, 5% or less pumice. Greater than 10 mesh: (i.e., plus No. 10 mesh sieved fraction): 90-95% volcanic lithics of intermediate to felsic composition. | | |
| | | | | | OTOWI MEMBER, BANDELIER TUFF: (80-85 ft) Volcanic tuff, yellowish brown (10YR 5/4). Greater than 35 mesh: 30% quartz & sanidine crystals, 40% pumice, 30% volcanic lithics. Greater than 10 mesh: andesite porphyry and various other volcanic lithics, 15% pumice & crystals. | | |

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BOREHOLE LOG

| | | |
|---|---|---|
| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 2 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | | SAMPLING EQ/METHOD: Cuttings |
| GROUND ELEVATION: 6779.2 ft<br>DRILLER: Thoren, Wilson, Brown | | TOTAL DEPTH = 1097 ft bgs<br>GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) | Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|---|---|
| 85 | | | | | | | OTOWI MEMBER, BANDELIER TUFF: (85-105 ft) Volcanic tuff, pale yellowish brown (10YR 5/4). Greater than 35 mesh: 65-85% quartz and sanidine crystals, 15-30% volcanic lithics, 10-15% pumice. Greater than 10 mesh: 80-90% volcanic lithics of intermediate to felsic composition, up to 10% pumice and quartz and sanidine crystals. | | |
| 90 | 6690 | | | | | | | | |
| 95 | 6685 | | | | | | | | |
| 100 | 6680 | | | | | | | | |
| 105 | 6675 | | | | | | OTOWI MEMBER, BANDELIER TUFF: (105-135 ft) Volcanic tuff, pale yellow brown (10YR 5/4). Greater than 35 mesh: 35-60% quartz and sanidine phenocrysts, 40% volcanic lithics, up to 25% pumice. Greater than 10 mesh: 85-95% lithic fragments of intermediate volcanic composition, 5% pumice and quartz and sanidine crystals. | | |
| 110 | 6670 | | | | | | | | |
| 115 | 6665 | | | | | | | | |
| 120 | 6660 | | | | | | | | |
| 125 | 6655 | | | | | | | | |
| 130 | 6650 | | | | | | | | |
| 135 | 6645 | | | | | | OTOWI MEMBER, BANDELIER TUFF: (135-165 ft) Volcanic tuff, medium yellowish brown (10YR 5/4). Greater than 35 mesh: 60-85% quartz and sanidine phenocrysts, 15-30% volcanic lithic fragments. Greater than 10 mesh: 70-95% volcanic lithic fragments (dominantly andesite porphyry), 10-30% quartz and sanidine crystals and locally minor pumice. | | |
| 140 | 6640 | | | | | | | | |
| 145 | 6635 | | | | | | | | |
| 150 | 6630 | | | | | | | | Qbo |
| 155 | 6625 | | | | | | | | |
| 160 | 6620 | | | | | | | | |
| 165 | 6615 | | | | | | OTOWI MEMBER, BANDELIER TUFF: (165-180 ft) Volcanic tuff, moderate yellowish brown (10YR 5/4). Greater than 35 mesh: 65-85% quartz and sanidine crystals, 10-15% volcanic lithics, 15-20% pumice. Greater than 10 mesh: 15-40% volcanic lithic fragments of andesitic to dacitic composition, 20-60% pumice and quartz and sanidine crystals. | | |
| 170 | 6610 | | | | | | | | |
| 175 | 6605 | | | | | | | | |
| 180 | 6600 | | | | | | | | |

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BOREHOLE LOG

| | | |
|---|---|---|
| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 3 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | SAMPLING EQ/METHOD: Cuttings | |
| GROUND ELEVATION: 6779.2 ft<br>DRILLER: Thoren, Wilson, Brown | | TOTAL DEPTH = 1097 ft bgs<br>GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) | Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|---|---|
| 180 | | | | | | | OTOWI MEMBER, BANDELIER TUFF: (180-200 ft) Volcanic tuff, yellowish brown (10YR 5/4). Greater than 35 mesh: 30% quartz and sanidine crystals, 30% pumice, 40% diverse volcanic rock fragments. Greater than 10 mesh: 70% pumice, 30% intermediate volcanic rock fragments. | | |
| 185 | 6595 | | | | | | | | |
| 190 | 6590 | | | | | | | | |
| 195 | 6585 | | | | | | | | |
| 200 | 6580 | | | | | | OTOWI MEMBER, BANDELIER TUFF: (200-215 ft) Volcanic tuff, medium yellow brown (10YR 5/4). Greater than 35 mesh: 60% quartz and sanidine crystals; 40% volcanic lithic fragments of intermediate composition. Greater than 10 mesh: 90% volcanic rock fragments of intermediate composition, 10% pumice and crystals. | | |
| 205 | 6575 | | | | | | | | |
| 210 | 6570 | | | | | | | | |
| 215 | 6565 | | | | | | OTOWI MEMBER, BANDELIER TUFF: (215-245 ft) Volcanic tuff, yellowish brown (5YR 5/4). Greater than 35 mesh: 30-65% quartz and sanidine crystals, 30-40% volcanic lithic fragments, 10-33% pumice fragments. Greater than 10 mesh: 10-40% pumice and quartz and sanidine crystals, 60-90% lithic fragments of intermediate to felsic composition. | | |
| 220 | 6560 | | | | | | | | |
| 225 | 6555 | | | | | | | | |
| 230 | 6550 | | | | | | | | |
| 235 | 6545 | | | | | | | | |
| 240 | 6540 | | | | | | | | Qbo |
| 245 | 6535 | | | | | | OTOWI MEMBER, BANDELIER TUFF: (245-260 ft) Volcanic tuff, moderate yellow brown (10YR 5/4). Greater than 35 mesh: 30-80% quartz & sanidine crystals, 10-30% lithic fragments predominantly of intermediate volcanic composition, locally up to 30% pumice. Greater than 10 mesh: 30-50% pumice fragments, 30-60% quartz & sanidine crystals. | | |
| 250 | 6530 | | | | | | | | |
| 255 | 6525 | | | | | | | | |
| 260 | 6520 | | | | | | OTOWI MEMBER, BANDELIER TUFF: (260-270 ft) Volcanic tuff, light yellowish brown (10YR 6/4). Greater than 35 mesh: 70-80% quartz and sanidine crystals, 20-30% volcanic rock fragments, mainly of intermediate composition. Greater than 10 mesh: 80-90% intermediate volcanic rock fragments, 10-20% felsic volcanic rock fragments, minor vitrophyre. | | |
| 265 | 6515 | | | | | | | | |
| 270 | 6510 | | | | | | | | |

LOS ALAMOS NATIONAL LABORATORY
ENVIRONMENTAL RESTORATION PROJECT,
GROUND WATER INVESTIGATIONS FOCUS AREA
BOREHOLE LOG

| | | |
|---|---|---|
| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 4 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | SAMPLING EQ/METHOD: Cuttings | |
| GROUND ELEVATION: 6779.2 ft | | TOTAL DEPTH = 1097 ft bgs |
| DRILLER: Thoren, Wilson, Brown | | GEOLOGIST: R. Lawrence |

Depth (ft): 270, 275, 280, 285, 290, 295, 300, 305, 310, 315, 320, 325, 330, 335, 340, 345

Elevation (ft): 6505, 6500, 6495, 6490, 6485, 6480, 6475, 6470, 6465, 6460, 6455, 6450, 6445, 6440, 6435

| Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|
| | | 270–302 ft | | | OTOWI MEMBER, BANDELIER TUFF: (270-285 ft) Volcanic tuff, moderate yellowish brown (10YR 5/4). Greater than 35 mesh: 40-90% quartz and sanidine crystals, 10-60% white (5YR 8/1) pumice. Greater than 10 mesh: 40-80% volcanic rock fragments of intermediate to felsic composition, minor local black vitrophyre, 10-50% white pumice. Base of Qbo ash flow tuffs at 285 ft bgs marked by increased dominance of pumice and quartz and sanidine crystals. | | Qbo |
| | | | | | GUAJE PUMICE BED: (285-302 ft) Air-fall tuff, pale brownish gray (5YR 6/1). Greater than 35 mesh: 50-60% white (5YR 8/1) pumice, 30-40% quartz and sanidine crystals, up to 20% various intermediate volcanic rocks, minor black vitrophyre. Greater than 10 mesh: 85% pumice, 10-15% intermediate volcanic rocks, quartz and sanidine crystals, locally clay-rich matrix. | | Qbog |
| | | | | | GUAJE PUMICE BED: (302-312 ft) No sample recovery; cuttings too fine to capture with sieve. | | |
| | | 312–347 ft | Geologic (312-322 ft) | | GUAJE PUMICE BED: (312-322 ft) Air-fall tuff, light brownish gray (5YR 6/1). Greater than 35 mesh: 50-70% quartz and sanidine crystals, 25-50% pumice, 5-20% volcanic lithics. Greater than 10 mesh: 50% white (5 YR 8/1) pumice, 50% porphyritic andesite (fragments up to 20 mm) and felsic volcanic rocks. WR sample has matrix of clay-size glass shards that lend cohesive cementation to volcanic clasts and grains. | | |
| | | | Geologic (327-332 ft) | | GUAJE PUMICE BED: (322-347 ft) Air-fall tuff, light brownish gray (5YR 6/1). Greater than 35 mesh: 40-90% pumice, 10-60% quartz and sanidine crystals. Greater than 10 mesh: 80-98% white (N8) vitric pumice fragments exhibiting frothy texture, 5-20% quartz and sanidine crystals and volcanic rock fragments. Base of Guaje Pumice Bed at approximately 347 ft bgs; contact marked by sandy gravel texture of underlying Puye Fanglomerate, abrupt decrease in pumice content, and concurrent increase in volcanic lithics of felsic to intermediate volcanic composition. | | |
| | | | | | PUYE FORMATION: (347-352 ft) Clastic sediments. Sandy gravel (GW), medium light gray (N6) with white mottling, small pebbles up to 5 mm. Clasts made up of 85-90% siliceous to intermediate volcanic lithics, 10-15% pumice (occurrence of pumice decreasing downward in interval), 1% glass. | | |

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BOREHOLE LOG

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| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 5 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | | SAMPLING EQ/METHOD: Cuttings |
| GROUND ELEVATION: 6779.2 ft | | TOTAL DEPTH = 1097 ft bgs |
| DRILLER: Thoren, Wilson, Brown | | GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) | Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|---|---|
| 350 | 6430 | | | | | | PUYE FORMATION: (347-352 ft) Clastic sediments. Sandy gravel (GW), medium light gray (N6) with white mottling, small pebbles up to 5 mm. Clasts made up of 85-90% siliceous to intermediate volcanic lithics, 10-15% pumice (occurrence of pumice decreasing downward in interval), 1% glass. | | |
| 355 | 6425 | | | | | | | | |
| 360 | 6420 | | | | | | PUYE FORMATION: (352-367 ft) Clastic sediments. Silty to clayey gravel (GM/GC), grayish orange pink (5YR 7/2); angular to subrounded clasts. Clasts are composed of volcanic rock compositions similar to 347-352 ft. | | |
| 365 | 6415 | | | | | | | | |
| 370 | 6410 | | | | Geologic (367-372 ft) | | PUYE FORMATION: (367-382 ft) Clastic sediments. Similar to above, 1-2% fines; less than 1% pumice; gravel clasts angular to subrounded. | | |
| 375 | 6405 | | | | Geologic (372-377 ft) | | | | |
| 380 | 6400 | | | | | | | | |
| 385 | 6395 | | | | Geologic (382-392 ft) | | PUYE FORMATION: (382-397 ft) Clastic sediments. Silty sandy gravel (GM), pale yellowish brown (10YR 6/2), 5% fines, 10% very fine to very coarse sand, 85% granules and small pebbles. Clasts are composed of 15% pumice, 85% porphyritic intermediate volcanic rocks. | | Tpf |
| 390 | 6390 | | | | | | | | |
| 395 | 6385 | | | | | | | | |
| 400 | 6380 | | | | | | PUYE FORMATION: (397-407 ft) Clastic sediments. Silty to clayey sandy gravel (GM/GC), grayish orange pink (5YR 7/2), 10% fines, 10-15% very fine to very coarse sand, 75% granules/pebbles that are subangular to subrounded. Clasts are composed of siliceous to intermediate volcanic rocks, minor glass. | | |
| 405 | 6375 | | | | | | | | |
| 410 | 6370 | | | | | | PUYE FORMATION: (407-422 ft) Clastic sediments. Gravel (GW), medium light gray (N6), pebbles up to 10 mm, angular to subrounded. Clasts are composed of intermediate to siliceous, porphyritic volcanic rocks. | | |
| 415 | 6365 | | | | | | | | |
| 420 | 6360 | | | | | | | | |
| 425 | 6355 | | | | | | PUYE FORMATION: (422-427 ft) Clastic sediments. Gravel (GW), light brownish gray (5YR 6/1), granules up to 2.5 mm, angular to subrounded. Clasts are composed of various porphyritic volcanic rocks. | | |

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| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 6 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | SAMPLING EQ/METHOD: Cuttings | |
| GROUND ELEVATION: 6779.2 ft<br>DRILLER: Thoren, Wilson, Brown | | TOTAL DEPTH = 1097 ft bgs<br>GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) | Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|---|---|
| 430 | 6350 | | | | | | PUYE FORMATION: (427-432 ft) Clastic sediments. Silty sandy gravel (GM), pale yellowish brown (10YR 6/2), 80-90% granules and small pebbles, 10% very fine to very coarse sand, 10-15% fines. Clasts are composed of 85% porphyritic volcanic rocks, 1% pumice, 2% glass, plus mafic minerals (biotite and hornblende). | | |
| 435 | 6345 | | | | | | | | |
| 440 | 6340 | | | | | | PUYE FORMATION: (432-452 ft) Clastic sediments. Silty sandy gravel (GM), grayish orange (10YR 7/4), 70-75% pebbles,15-20% very fine to very coarse sand, 10% fines. Greater than 10 mesh: clasts are made up of siliceous, porphyritic (mafic phenocrysts, biotite, and hornblende) intermediate and mafic volcanic rocks; 1% glass. | | |
| 445 | 6335 | | | | | | | | |
| 450 | 6330 | | | | | | | | |
| 455 | 6325 | | | | | | PUYE FORMATION: (452-482 ft) Clastic sediments. Silty sandy gravel (GM), pale yellowish brown (10YR 6/2) 10-15% fines, 10-15% very fine to very coarse sand, 70% gravel, angular to subrounded pebbles up to 20 mm. Clasts are composed of siliceous to intermediate porphyritic volcanic rocks with phenocrysts of feldspar (up to 3 mm), biotite, and hornblende (up to 1 mm), 1 % glass. | | |
| 460 | 6320 | | | | | | | | |
| 465 | 6315 | | | | | | | | |
| 470 | 6310 | | | | | | | | Tpf |
| 475 | 6305 | | | | | | | | |
| 480 | 6300 | | | | | | | | |
| 485 | 6295 | | | | Geologic (482-487 ft) | | PUYE FORMATION: (482-497 ft) Clastic sediments. Silty sandy gravel (GM), pale orange (10YR 8/2), 75-80% pebbles (up to 15 mm), 10-15% very fine to coarse sand, 10% fines; clasts angular to subrounded. Greater than 10 mesh: predominantly siliceous to intermediate porphyritic volcanic rocks, minor mafic volcanics with phenocrysts of feldspar, 1% vitrophyre. | | |
| 490 | 6290 | | | | | | | | |
| 495 | 6285 | | | | | | | | |
| 500 | 6280 | | | | | | PUYE FORMATION: (497-512 ft) Clastic sediments. Clayey gravel (GC), grayish orange (10YR 7/4), pebbles up to 18 mm, subangular to subrounded. Clasts are composed of siliceous porphyritic volcanic rocks, pumice, and quartz crystals. | | |
| 505 | 6275 | | | | Geologic (497-517 ft) | | | | |
| 510 | 6270 | | | | | | | | |

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BOREHOLE LOG

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| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 7 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | | SAMPLING EQ/METHOD: Cuttings |
| GROUND ELEVATION: 6779.2 ft | | TOTAL DEPTH = 1097 ft bgs |
| DRILLER: Thoren, Wilson, Brown | | GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) | Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|---|---|
| 515 | 6265 | | | | | | PUYE FORMATION: (512-522 ft) Clastic sediments. Clayey gravel (GC), yellowish brown (10YR 6/2), pebbles up to 10 mm, subangular to subrounded. Clasts are composed mainly of felsic volcanic rocks. | | |
| 520 | 6260 | | | | | | | | |
| 525 | 6255 | | | | | | PUYE FORMATION: (522-542 ft) Clastic sediments. Sandy gravel (GW), pale yellowish brown (10YR 6/2), fine to coarse sand, pebbles up to 19 mm, subangular to subrounded. Clasts are composed of porphyritic dacite. | | |
| 530 | 6250 | | | | | | | | |
| 535 | 6245 | | | | | | | | |
| 540 | 6240 | | | | | | | | |
| 545 | 6235 | | | | | | PUYE FORMATION: (542-557 ft) Clastic sediments. Sandy gravel (GW), pale brown (5YR 5/2), pebbles up to 20 mm. Clasts are composed of porphyritic dacite, pumice, other felsic volcanics, and basalt. | | |
| 550 | 6230 | | | | | | | | |
| 555 | 6225 | | | | | | | | Tpf |
| 560 | 6220 | | | | | | PUYE FORMATION: (557-572 ft) Clastic sediments. Sandy gravel (GW), pale brown (5YR 5/2), 10% fines, 90% sandy pebble gravel up to 14 mm, angular to subrounded. Clasts are composed of 80% porphyritic felsic volcanics, 10% pumice and quartz crystals. | | |
| 565 | 6215 | | | | | | | | |
| 570 | 6210 | | | | Geologic (567-572 ft) | | | | |
| 575 | 6205 | | | | | | PUYE FORMATION: (572-592 ft) Clastic sediments. Silty sandy gravel (GW), yellowish brown (10YR 6/2), 80% sand/gravel (angular to subrounded pebbles up to 14 mm), 20% fines. Clasts are composed of 80% porphyritic andesite and dacite. | | |
| 580 | 6200 | | | | | | | | |
| 585 | 6195 | | | | | | | | |
| 590 | 6190 | | | | | | | | |
| 595 | 6185 | | | | | | PUYE FORMATION: (592-602 ft) Clastic sediments. Sandy gravel (GW), light brownish gray (5YR 6/1), 10% fines, pebbles up to 20 mm. Clasts are composed of 90% felsic to intermediate volcanic lithic fragments. | | |
| 600 | 6180 | | | | | | | | |

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| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 8 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | | SAMPLING EQ/METHOD: Cuttings |
| GROUND ELEVATION: 6779.2 ft | | TOTAL DEPTH = 1097 ft bgs |
| DRILLER: Thoren, Wilson, Brown | | GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) | Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|---|---|
| 605 | 6175 | | | | | | PUYE FORMATION: (602-617 ft) Clastic sediments. Clayey, silty gravel (GC/GM), pale yellowish brown (10YR 6/2), pebbles up to 20 mm, angular to subrounded. Clasts are composed mostly of porphyritic dacite and andesite, minor pumice, and a small percentage of quartz and feldspar crystals. | | |
| 610 | 6170 | | | | | | | | |
| 615 | 6165 | | | | | | | | |
| 620 | 6160 | | | | | | PUYE FORMATION: (617-622 ft) Clastic sediments. Gravelly sand (SW), dark yellowish brown (10YR 4/2), very fine to very coarse sand, grains subangular to subrounded, pebbles up to 8 mm. Clasts are composed of felsic volcanic lithics and quartz and sanidine crystals. | | |
| 625 | 6155 | | | | | | PUYE FORMATION: (622-652 ft) Clastic sediments. Silty gravel (GM), light brownish gray (5YR 6/1), pebbles up to 26 mm, subangular to subrounded. Clasts composed of felsic to intermediate volcanic rocks, quartz and feldspar crystals. | | |
| 630 | 6150 | | | | | | | | |
| 635 | 6145 | | | | | | | | |
| 640 | 6140 | | | | | | | | |
| 645 | 6135 | | | | | | | | |
| 650 | 6130 | | | | | | | | |
| 655 | 6125 | | | | | | PUYE FORMATION: (652-662 ft) Clastic sediments. Gravelly sand (SW), pale yellowish brown (10YR 6/2), fine to very coarse sand, grains subangular to subrounded, pebbles up to 12 mm. Clasts are composed of felsic to intermediate volcanic rocks, quartz and feldspar crystals | | Tpf |
| 660 | 6120 | | | | | | | | |
| 665 | 6115 | | | | | | PUYE FORMATION: (662-682 ft) Clastic sediments. Sandy gravel (GW), pale brown (5YR 5/2), pebbles up to 13 mm, subangular to subrounded. Clasts composed of felsic to intermediate volcanic rocks, quartz and feldspar crystals. | | |
| 670 | 6110 | | | | Geologic (667-672 ft) | | | | |
| 675 | 6105 | | | | | | | | |
| 680 | 6100 | | | | | | | | |
| 685 | 6095 | | | | | | PUYE FORMATION: (682-702 ft) Clastic sediments. Sandy gravel (GW), pale yellowish brown (10YR 6/2), pebbles up to 10 mm, subrounded to angular. Clasts composed of felsic to intermediate volcanic rocks, quartz and feldspar crystals. | | |
| 690 | 6090 | | | | | | | | |

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| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 9 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | | SAMPLING EQ/METHOD: Cuttings |
| GROUND ELEVATION: 6779.2 ft | | TOTAL DEPTH = 1097 ft bgs |
| DRILLER: Thoren, Wilson, Brown | | GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) | Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|---|---|
| 695 | 6085 | | | | | | PUYE FORMATION: (682-702 ft) Clastic sediments. Sandy gravel (GW), pale yellowish brown (10YR 6/2), pebbles up to 10 mm, subrounded to angular. Clasts composed of felsic to intermediate volcanic rocks, quartz and feldspar crystals. | | |
| 700 | 6080 | | | | | | | | |
| 705 | 6075 | | | | | | PUYE FORMATION: (702-717 ft) Clastic sediments. Clayey to silty gravel (GC/GM), yellowish tan (10YR 6/4), pebbles up to 7 mm. Clasts composed predominantly of light gray (N6) porphyritic andesite. Greater than 35 mesh: contains less than 5% quartz and feldspar crystals. | | |
| 710 | 6070 | | | | | | | | Tpf |
| 715 | 6065 | | | | | | | | |
| 720 | 6060 | | | | | | PUYE FORMATION: (717-737 ft) Clastic sediments. Sandy gravel (GW), pale yellowish brown (10YR 6/2), pebbles up to 13 mm, subangular to subrounded, very coarse sandy matrix. Greater than 10 mesh: 60-70% of clasts made up of porphyritic andesite, 30-40% dacite to rhyolite. Greater than 35 mesh: contains less than 5% quartz and feldspar crystals. | | |
| 725 | 6055 | | | | Geologic (722-727 ft) | | | | |
| 730 | 6050 | | | | | | | | |
| 735 | 6045 | | | | | | | | |
| 740 | 6040 | | | | Geologic (737-742 ft) | | PUYE FORMATION (PUMICEOUS): (737-742 ft) Clastic sediments. Silty sandy gravel (GM), yellowish tan (10YR 6/2), pebble clasts up to 10 mm, subangular to subrounded, silty matrix. Greater than 10 mesh: 80% of clasts made up of porphyritic andesite, 15% white (5YR 8/1) pumice and porphyritic dacite, 5% granules of tuffaceous siltstone. Greater than 35 mesh: contains up to 10% quartz and feldspar crystals. | | |
| 745 | 6035 | | | | Geologic (742-747 ft) | | | | |
| 750 | 6030 | | | | | | | | Tpp |
| 755 | 6025 | | | | | | PUYE FORMATION (PUMICEOUS): (742-767 ft) Clastic sediments. Sandy gravel (GW), yellowish tan (10YR 7/4), granules/pebbles up to 10 mm, very coarse sand matrix. Greater than 10 mesh: 50-70% of clasts made up of white (5YR 8/1) pumice and biotite-dacitic porphyry, 30-50% diverse intermediate volcanic rocks; Greater than 35 mesh: contains at least 30% quartz and feldspar crystals. | | |
| 760 | 6020 | | | | | | | | |
| 765 | 6015 | | | | | | | | |
| 770 | 6010 | | | | | | PUYE FORMATION (PUMICEOUS): (767-772 ft) Clastic sediments. Silty sandy gravel (GM), yellow tan (10YR 7/4), pebble gravel with matrix consisting of silt-sized glass shards. Clasts are composed of 60% porphyritic andesite, 40% pumice and other dacite to rhyolite clasts. | | |

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BOREHOLE LOG

| | | |
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| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 10 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | | SAMPLING EQ/METHOD: Cuttings |
| GROUND ELEVATION: 6779.2 ft | | TOTAL DEPTH = 1097 ft bgs |
| DRILLER: Thoren, Wilson, Brown | | GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) | Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|---|---|
| 775 | 6005 | | | | | | PUYE FORMATION (PUMICEOUS): (772-777 ft) Clastic sediments. Clayey sand (SC), yellow tan (10YR 7/4), very coarse sand to granules with silty volcanic ash matrix. Greater than 10 mesh: 90-95% pumice and felsic volcanic rocks. | | |
| 780 | 6000 | | | | | | PUYE FORMATION (PUMICEOUS): (777-797 ft) Clastic sediments. Sandy gravel (GW), pinkish tan (5YR 7/2), pebbles up to 15 mm, local volcanic ash matrix. Interval is generally pumice rich. Greater than 10 mesh: 80-95% white (5YR 8/1) pumice, dacite, rhyolite; 5-20% various intermediate volcanic rocks. Greater than 35 mesh: contains abundant quartz and feldspar crystals. | | |
| 785 | 5995 | | | | | | | | |
| 790 | 5990 | | | | Geologic (787-792 ft) | | | | |
| 795 | 5985 | | | | | | | | |
| 800 | 5980 | | | | | | PUYE FORMATION (PUMICEOUS): (797-812 ft) Clastic sediments. Silty gravel (GM), pale yellow brown (5YR 7/2) coarse granules to pebbles (up to 7 mm) with silty (volcanic ash) matrix. Greater than 10 mesh: 40-50% of clasts made up of various intermediate volcanic rocks. Greater than 35 mesh: contains 5% quartz and feldspar crystals. | | |
| 805 | 5975 | | | | | | | | |
| 810 | 5970 | | | | | | | | Tpp |
| 815 | 5965 | | | | | | PUYE FORMATION (PUMICEOUS): (812-832 ft) Clastic sediments. Sandy gravel (GW), pale grayish tan (5YR 7/2), pebbles (up to 10 mm) with fine to coarse sand matrix. Greater than 10 mesh: 70-80% of clasts made up of intermediate volcanic rocks; 20-30% pumice, rhyolite, dacite; locally minor basalt and obsidian. | | |
| 820 | 5960 | | | | | | | | |
| 825 | 5955 | | | | Geologic (817-827 ft) | | | | |
| 830 | 5950 | | | | | | | | |
| 835 | 5945 | | | | | | PUYE FORMATION (PUMICEOUS): (832-847 ft) Clastic sediments. Silty gravel (GM), yellowish tan (5YR 7/2), pebbles (up to 15 mm) with fine sand to silty (volcanic ash) matrix. Greater than 10 mesh: 90% of clasts made up of pumice and felsic volcanic rocks (grading downward in the interval to predominantly andesite), minor basalt, and spherical clumps of silty ash. | | |
| 840 | 5940 | | | | | | | | |
| 845 | 5935 | | | | Geologic (842-847 ft) | | | | |
| 850 | 5930 | | | | | | PUYE FORMATION (PUMICEOUS): (847-852 ft) No sample recovery; cuttings too fine to capture with sieve. | | |
| 855 | 5925 | | | | | | PUYE FORMATION (PUMICEOUS): (852-857 ft) Clastic sediments. Sand (SW), pinkish tan (5YR 6/4), fine to very coarse sand with volcanic ash matrix. Greater than 10 mesh: 75% of clasts are rounded granules of tuffaceous siltstone, 25% intermediate volcanic rock fragments. Greater than 35 mesh: contains abundant pumice | | |

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BOREHOLE LOG

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| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 11 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | | SAMPLING EQ/METHOD: Cuttings |
| GROUND ELEVATION: 6779.2 ft | | TOTAL DEPTH = 1097 ft bgs |
| DRILLER: Thoren, Wilson, Brown | | GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) | Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|---|---|
| 860 | 5920 | | | | Geologic (857-862 ft) | | PUYE FORMATION (PUMICEOUS): (857-862 ft) Clastic sediments. Sandy gravel (GW), pebbles up to 7 mm with fine to medium sand matrix. Pumice-rich interval. Greater than 10 mesh: clasts are composed of 95-97% pumice and other felsic volcanic rock fragments. | | |
| 865 | 5915 | | | | | | | | |
| 870 | 5910 | | | | | | PUYE FORMATION (PUMICEOUS): (862-887 ft) Clastic sediments. Sand (SW), pinkish tan (5YR 6/4), fine to very coarse sand. Clasts are composed of 70-80% pumice and other felsic volcanic rocks, 20-30% various rocks of intermediate volcanic composition, minor obsidian and basalt. | | |
| 875 | 5905 | | | | | | | | |
| 880 | 5900 | | | | | | | | |
| 885 | 5895 | | | | Geologic (882-887 ft) | | | | |
| 890 | 5890 | | | | | | PUYE FORMATION (PUMICEOUS): (887-892 ft) Clastic sediments. Sand (SP), pinkish tan (5YR 6/4), very fine to medium sand. Greater than 35 mesh: 80% pumice, 15% various volcanic rock fragments, 5% quartz-feldspar crystals. | | |
| 895 | 5885 | | | | | | | | |
| 900 | 5880 | | | | | | PUYE FORMATION (PUMICEOUS): (892-912 ft) Clastic sediments. Sandy gravel (GW), pebbles up to 15 mm, angular to subrounded, medium to very coarse sand matrix. Greater than 10 mesh: clasts are composed of intermediate to felsic (andesite, dacite, rhyolite) volcanic rocks, some rounded tuffaceous siltstone, some pumice, minor basalt. Greater than 35 mesh: abundant pumice, quartz-feldspar crystals, minor clay in matrix. | | Tpp |
| 905 | 5875 | | | | Geologic (902-907 ft) | | | | |
| 910 | 5870 | | | | | | | | |
| 915 | 5865 | | | | Geologic (912-917 ft) | | PUYE FORMATION (PUMICEOUS): (912-927 ft) Clastic sediments. Sandy gravel (GW), pinkish tan (5YR 6/4), pebbles up to 10 mm with fine to medium sand matrix. Pumice-rich interval. Greater than 10 mesh: 85-95% white (5YR 8/1) pumice, 5-15% gray (N7) porphyritic andesite and dacite. | | |
| 920 | 5860 | | | | Geologic (917-927 ft) | | | | |
| 925 | 5855 | | | | | | | | |
| 930 | 5850 | | | | Geologic (927-932 ft) | | PUYE FORMATION (PUMICEOUS): (927-937 ft) Clastic sediments. Sandy gravel (GW), varicolored, pebbles up to 15 mm, fine to very coarse sand matrix. Greater than 10 mesh: 50% white (5YR 8/1) felsic volcanic rocks and pumice, 30% andesite and dacite, 20% basalt. | | |
| 935 | 5845 | | | | | | | | |

LOS ALAMOS NATIONAL LABORATORY
ENVIRONMENTAL RESTORATION PROJECT,
GROUND WATER INVESTIGATIONS FOCUS AREA
BOREHOLE LOG

| | | |
|---|---|---|
| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 12 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | | SAMPLING EQ/METHOD: Cuttings |
| GROUND ELEVATION: 6779.2 ft<br>DRILLER: Thoren, Wilson, Brown | | TOTAL DEPTH = 1097 ft bgs<br>GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) | Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|---|---|
| 940 | 5840 | | | | | | PUYE FORMATION (PUMICEOUS): (937-952 ft) Clastic sediments. Sandy gravel (GW), pinkish tan (5YR 6/4), pebbles up to 10 mm, fine to very coarse sand matrix. Greater than 10 mesh: 30-70% felsic volcanic rocks and some pumice, 30-70% andesite, dacite, basalt. Greater than 35 mesh: abundant pumice, quartz and feldspar crystals. | | |
| 945 | 5835 | | | | | | | | |
| 950 | 5830 | | | | | | | | |
| 955 | 5825 | | | | | | PUYE FORMATION (PUMICEOUS): (952-962 ft) Clastic sediments. Sandy gravel (GW), pebbles up to 15 mm, very fine to coarse sand matrix with local clay content. Greater than 10 mesh: 25-80% pumice, rhyolite, and ash; 20-75% andesite, dacite, basalt. Greater than 35 mesh: abundant pumice, quartz and feldspar crystals. | | |
| 960 | 5820 | | | | | | | | |
| 965 | 5815 | | | | | | PUYE FORMATION (PUMICEOUS): (962-982 ft) Clastic sediments. Sand (SP), pinkish tan (5YR 6/4) to varicolored, very coarse sand with granules up to 4 mm. Greater than 10 mesh: 50-90% white (5YR 8/1) rhyolite, rhyodacite, pumice fragments; 10-50% andesite, dacite, basalt (locally scoriaceous). Greater than 35 mesh: abundant quartz and feldspar crystals. | | |
| 970 | 5810 | | | | | | | | |
| 975 | 5805 | | | | Geologic (972-977 ft) | | | | |
| 980 | 5800 | | | | | | | | Tpp |
| 985 | 5795 | | | | Geologic (982-987 ft) | | PUYE FORMATION (PUMICEOUS): (982-997 ft) Clastic sediments. Clayey gravel (GC), pinkish tan (5YR 6/4), pebbles up to 15 mm, clasts subrounded to angular, very fine sand to clay matrix. Greater than 10 mesh: 40-50% felsic volcanic rocks and pumice; 50-60% andesite, dacite, and minor basalt. Greater than 35 mesh: abundant quartz and feldspar crystals. | | |
| 990 | 5790 | | | | | | | | |
| 995 | 5785 | | | | | | | | |
| 1000 | 5780 | | | | | | PUYE FORMATION (PUMICEOUS): (997-1022 ft) Clastic sediments. Clayey gravel (GC), yellow tan (5YR 7/2) to grayish brown (5YR 6/1), pebbles up to 10 mm, fine sand to clayey matrix. Greater than 10 mesh: 80% andesite, dacite, and minor basalt; 20% white felsic volcanic clasts. Greater than 35 mesh: abundant quartz and feldspar crystals, clayey matrix. | | |
| 1005 | 5775 | | | | | | | | |
| 1010 | 5770 | | | | | | | | |
| 1015 | 5765 | | | | | | | | |
| 1020 | 5760 | | | | | | | | |

LOS ALAMOS NATIONAL LABORATORY
ENVIRONMENTAL RESTORATION PROJECT,
GROUND WATER INVESTIGATIONS FOCUS AREA
BOREHOLE LOG

| | | |
|---|---|---|
| BOREHOLE ID: R-7 | TA/OU: TA-53 | Page 13 of 13 |
| DRILLING COMPANY: Dynatec | Start Date: 12/00 | Finish Date: 1/01 |
| DRILLING EQ/METHOD: Foremost DR24 | | SAMPLING EQ/METHOD: Cuttings |
| GROUND ELEVATION: 6779.2 ft | | TOTAL DEPTH = 1097 ft bgs |
| DRILLER: Thoren, Wilson, Brown | | GEOLOGIST: R. Lawrence |

| Depth (ft) | Elevation (ft) |
|---|---|
| 1025 | 5755 |
| 1030 | 5750 |
| 1035 | 5745 |
| 1040 | 5740 |
| 1045 | 5735 |
| 1050 | 5730 |
| 1055 | 5725 |
| 1060 | 5720 |
| 1065 | 5715 |
| 1070 | 5710 |
| 1075 | 5705 |
| 1080 | 5700 |
| 1085 | 5695 |
| 1090 | 5690 |
| 1095 | 5685 |
| 1100 | 5680 |

| Core Run # (amt.-recov./amt. attemp.) | Core Run | Cuttings Collected | Geologic Characterization (Depth Interval) | Moisture/Matric Pot. | Lithology | Graphic Log | Lithologic Symbol |
|---|---|---|---|---|---|---|---|
| | | 1022-1084 ft | | | PUYE FORMATION (PUMICEOUS): (1022-1037 ft) Clastic sediments. Poorly graded sand (SP), light gray to pinkish gray (5YR 6/1) coarse sand to granules up to 4 mm, subrounded, local minor clay in matrix. Clasts composed of 75-85% intermediate to felsic porphyritic volcanic rocks, 15-25% white (5YR 8/1) pumice, and other felsic volcanic rocks. | | Tpp |
| | | | Geologic (1047-1052 ft) | | PUYE FORMATION (PUMICEOUS): (1037-1052 ft) Clastic sediments. Well graded sand with pebble gravel (SW), varicolored to pinkish tan (5YR 6/4), 90% fine to very coarse sand, 10% granules/pebbles (up to 10 mm). Pumice-rich interval. Greater than 10 mesh: 70-80% rhyolite and pumice clasts, 20-30% gray porphyritic intermediate volcanic rocks. | | Tpp |
| | | | Geologic (1057-1062 ft) | | PUYE FORMATION (PUMICEOUS): (1052-1067 ft) Clastic sediments. Well graded sand (SW) with pebble gravel, medium gray (5YR 4/1) to varicolored, 5-10% fines, 85% very fine to coarse sand, 2-5% granules/pebbles up to 15 mm. Greater than 10 mesh: 70-95% andesite, dacite, and black (N6) vitrophyre; 20-30% pumice and rhyolite clasts (percentage of felsics decreasing rapidly downward in the interval); 1-2% quartzite clasts. | | Tpp |
| | | | | | PUYE FORMATION (PUMICEOUS): (1067-1084 ft) Clastic sediments. Silty sand (SM), pale yellowish brown (10YR 6/2) to light brown (5YR 5/2), 15% fines, 80-85% very fine to medium sand, 1-2% granules/pebbles up to 12 mm, angular to subrounded. Greater than 10 mesh: clasts composed predominantly of andesite and dacite, minor basalt and pumice, minor quartzite clasts. | | Tpp |
| | | | | | PUYE FORMATION (PUMICEOUS): (1084-1087 ft) No sample recovery. | | Tpp |
| | | 1087-1097 ft | Geologic (1087-1092 ft)<br>Geologic (1092-1097 ft) | | TOTAVI LENTIL: (1087-1097 ft) Clastic sediments. Well graded sand with gravel (SW), medium gray (N4), 85% fine to very coarse sand, 10% granules/pebbles up to 20 mm, 5% fines, clasts subangular to subrounded. Greater than 10 mesh: 70-80% andesite, 10-15% felsic volcanic rocks, 5-15% quartzite and rare granitic rocks, minor tuffaceous siltstone clasts, minor scoriaceous basalt. | | Tpt |

# Appendix C

*Thin-Section Petrography*

## APPENDIX C THIN-SECTION PETROGRAPHY

| | |
|---|---|
| R-7 312-322<br>2- to 4-mm size fraction | This polished thin section contains vitric pumice of the Guaje Pumice Bed with quartz and sanidine phenocrysts. Most of the 2- to 4-mm fragments in the section however are of varied lithic fragments, primarily of devitrified quartz-sanidine porphyritic tuff but including minor occurrences of plagioclase-orthopyroxene-clinopyroxene porphyritic dacite, a quartz-rich sandstone with birefringent clay matrix, and single fragments each of biotite-porphyritic dacite, trachytic feldspathic lava, a very fine grained lava (probably dacitic), and a muscovite-bearing quartzite with strained and sutured quartz grains. |
| R-7 327-332<br>2- to 4-mm size fraction | This polished thin section consists predominantly of vitric pumice of the Guaje Pumice Bed with quartz and sanidine phenocrysts. Lithic fragments include immature arkosic sandstone, altered dacitic lavas with sieved plagioclase phenocrysts, and a fragment of feldspathic dacite with twinned, unaltered clinopyroxene phenocrysts. |
| R-7 367-372<br>2- to 4-mm size fraction | This polished thin section contains a heterogeneous mixture of fragments from various dacitic lavas, including lava with acicular clinopyroxene phenocrysts and rare biotite and orthopyroxene (26%), lava with sieved plagioclase phenocrysts and altered biotite and amphibole phenocrysts (26%), and lava with phenocrysts of plagioclase and altered amphibole (13%). The remainder consists of 5 single fragments (~7% of each) of lava with resorbed quartz plus acicular clinopyroxene and orthopyroxene; lava with plagioclase, quartz, and altered amphibole; lava with quartz, plagioclase, and clinopyroxene; lava with plagioclase and a xenolith of polygonal quartz grains; and a heavily clay-altered lava (probably dacitic). |
| R-7 372-377<br>2- to 4-mm size fraction | This polished thin section contains a limited mixture of fragments dominated (56%) by a lava with acicular pyroxene and sieved plagioclase phenocrysts. Other lithologies include lava with phenocrysts of sieved plagioclase, quartz, and acicular amphibole (20%) and lava with phenocrysts of quartz and acicular pyroxene (16%). The remainder consists of two single fragments (~4% of each) of a fine-grained feldspathic dacite and an arkosic volcanic sandstone with detritus derived mainly from dacitic lithologies. |
| R-7 382-392<br>2- to 4-mm size fraction | This polished thin section contains a limited mixture of fragments dominated (80%) by a lava with acicular brown orthopyroxene phenocrysts with sieved plagioclase, quartz, and less common amphibole and blocky clinopyroxene phenocrysts. Other fragments include clay masses containing crystals of 0.2-1 mm plagioclase and 0.5 mm biotite. The remainder consists of two single fragments (~5% of each) of a brecciated plagioclase-clinopyroxene dacitic lava and a vitric pumice with quartz and sanidine phenocrysts. |
| R-7 482-487<br>2- to 4-mm size fraction | This polished thin section contains a limited mixture of fragments dominated (70%) by a lava with acicular brown orthopyroxene phenocrysts with sieved plagioclase, quartz, and less common altered amphibole and euhedral clinopyroxene phenocrysts. Other fragments include a plagioclase-clinopyroxene porphyritic dacite (23%) and immature micaceous (biotite) volcanic siltstone (7%). |
| R-7 497-517<br>2- to 4-mm size fraction | This polished thin section contains a limited mixture of fragments dominated (52%) by an immature volcanic siltstone mottled with included bodies of similar sandstone. Another 12% of the fragments are of porous immature volcanic sandstone. All of these sediments contain feldspar, quartz, clinopyroxene, and fragments of fine-grained dacitic lava matrix. Other fragments are of acicular orthopyroxene dacite (18%). The remainder consists of three single fragments (~6% of each) of a trachytic plagioclase-clinopyroxene porphyritic dacite, a trachytic quartz-porphyritic dacite, and a plagioclase-clinopyroxene porphyritic dacite. |
| R-7 567-572<br>2- to 4-mm size fraction | This polished thin section contains a limited mixture of fragments dominated (60%) by a lava with acicular orthopyroxene phenocrysts with sieved plagioclase, quartz, and blocky clinopyroxene phenocrysts. Some fragments also contain biotite. Other fragments are of plagioclase-clinopyroxene porphyritic dacite (20%), acicular orthopyroxene and clinopyroxene dacite (8%), and dacite with sieved plagioclase, acicular clinopyroxene, and biotite (8%), and a single fragment (~4%) of plagioclase-clinopyroxene porphyritic dacite with altered remnants of biotite and amphibole phenocrysts. |

| | |
|---|---|
| R-7 667-672<br>2- to 4-mm size fraction | This polished thin section contains a single homogeneous collection (100%) of fragments of dacite with sieved plagioclase, acicular orthopyroxene, blocky clinopyroxene, quartz, and altered amphibole; some fragments also contain sparse biotite phenocrysts. |
| R-7 722-727<br>2- to 4-mm size fraction | This polished thin section contains a single homogeneous collection (100%) of fragments of dacite with sieved plagioclase, acicular orthopyroxene, blocky clinopyroxene, quartz, and altered amphibole; some fragments also contain sparse, altered biotite phenocrysts. |
| R-7 737-742<br>2- to 4-mm size fraction | This polished thin section contains a limited mixture of fragments dominated (88%) by a lava with acicular orthopyroxene phenocrysts with sieved plagioclase, quartz, euhedral clinopyroxene, and biotite phenocrysts. Other fragments are of crystal-rich vitric pumice with albite, sanidine, and quartz phenocrysts (two fragments, ~8% of the sample), and a single fragment (~4% of the sample) of quartz-porphyritic dacite with a fine-grained matrix. |
| R-7 742-747<br>2- to 4-mm size fraction | This polished thin section contains a limited mixture of fragments dominated (50%) by a dacite lava with plagioclase phenocrysts with glass inclusions plus phenocrysts of quartz and acicular orthopyroxene; some fragments also contain biotite phenocrysts. Other fragments are of vitric pumice with phenocrysts of sieved plagioclase and biotite (20%), vitric pumice with plagioclase and sanidine phenocrysts plus rarer phenocrysts of quartz and biotite (10%), and clinopyroxene-biotite porphyritic dacite (10%). The remainder consists of two single fragments (~5% of each) of a quartz-biotite porphyritic dacite and a vitric pumice with plagioclase, hornblende, and biotite phenocrysts. |
| R-7 742-747 pum<br>Hand-picked fragments | This polished thin section contains vitric pumice fragments consisting primarily of porphyritic vitric pumice with phenocrysts of quartz, sanidine, albite, and lesser biotite and amphibole. |
| R-7 787-792 pum<br>Hand-picked fragments | This polished thin section contains vitric pumice fragments consisting predominantly (88%) of aphyric pumice with rare quartz and plagioclase crystals. The section also contains two fragments of a plagioclase-porphyritic pumice (6% of the sample) and two single fragments (each ~3% of the sample), one of a plagioclase-biotite porphyritic pumice and one of a fused mass of mm-size pumices with feldspar and quartz phenocrysts. |
| R-7 817-827<br>2- to 4-mm size fraction | This polished thin section contains a heterogeneous mixture of fragments from pumice and various dacitic lavas, including lava with sieved plagioclase and euhedral clinopyroxene and orthopyroxene phenocrysts (40%), mottled feldspathic dacite lava (18%), biotite-amphibole porphyritic dacite (10%), clinopyroxene-orthopyroxene porphyritic intersertal brown-glass vesicular lava (10%), and orthopyroxene-porphyritic vitric lava (7%). The remainder consists of five single fragments (~3% of each) of clinopyroxene-orthopyroxene-amphibole porphyritic lava with orange glass matrix, clinopyroxene and altered amphibole porphyritic lava, clinopyroxene porphyritic microgranular-matrix lava, a brown vitric pumice breccia with plagioclase, clinopyroxene, and amphibole phenocrysts, and an altered aphyric pumice. |
| R-7 842-847<br>2- to 4-mm size fraction | This polished thin section contains a heterogeneous mixture of fragments from pumice and various dacitic lavas, but consists mostly of sandstone and siltstone fragments including a volcanic siltstone with fragments of plagioclase, biotite and glass (27%), and volcanic sandstone with fragments of pumice and clay bodies (13%). Lithic constituents include dacitic lava with sieved plagioclase, clinopyroxene, and amphibole phenocrysts (17%), aphyric vitric pumice (10%), dacitic lava with sieved plagioclase, acicular amphibole, and large quartz phenocrysts (7%), trachytic lava with quartz and clinopyroxene phenocrysts (7%), and heavily altered lava (probably dacitic). The remainder consists of four single fragments (~3% of each) of clinopyroxene-orthopyroxene porphyritic lava, clinopyroxene-porphyritic vitric lava, plagioclase-quartz-acicular orthopyroxene porphyritic lava, and vitric pumice with trace biotite phenocrysts. |

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|---|---|
| R-7 857-872 pum Hand-picked fragments | This polished thin section contains vitric pumice fragments consisting predominantly (75%) of aphyric pumice. The section also contains 25% porphyritic pumice with phenocrysts of sanidine, plagioclase, and rarer quartz. |
| R-7 882-887 Hand-picked fragments | This polished thin section contains vitric pumice fragments consisting dominantly (90%) of aphyric pumice. The section also contains two fragments of a clinopyroxene-rich glassy dacite and one fragment of spherulitic devitrified pumice with sanidine phenocrysts. |
| R-7 902-907 2- to 4-mm size fraction | This polished thin section contains a heterogeneous mixture of fragments from pumice and various dacitic lavas, including aphyric vitric pumice (21%), porphyritic vitric pumice with either quartz and sanidine phenocrysts or fine laths of feldspar (8%), immature arkosic volcanic siltstone (17%), fine-grained clinopyroxene dacite (10%), clinopyroxene porphyritic dacitic vitrophyre (10%), and dacite lava with sieved plagioclase-clinopyroxene-amphibole phenocrysts (10%). The remainder consists of six single fragments (~4% of each) of crystal-poor quartz porphyry, dacitic lava with fine-grained plagioclase laths, amphibole-biotite porphyritic dacite, plagioclase-amphibole vitric dacite, spherulitic devitrified quartz-sanidine-plagioclase dacite, and a silicified volcanic lithology. |
| R-7 912-917 pum Hand-picked fragments | This polished thin section contains vitric pumice fragments consisting predominantly (85%) of pumice with rare phenocrysts of plagioclase, clinopyroxene, or biotite. The section also contains 15% porphyritic pumice with phenocrysts of plagioclase, quartz, and concentrically zoned sanidine. |
| R-7 912-917 2- to 4-mm size fraction | This polished thin section consists predominantly (70%) of aphyric pumice with rare sanidine and biotite phenocrysts. Other pumice types include porphyritic pumice with plagioclase phenocrysts (15%), porphyritic pumice with plagioclase-orthopyroxene-clinopyroxene phenocrysts (6%), and a single fragment (~3%) of porphyritic pumice with sanidine and embayed quartz phenocrysts. The remainder of the thin section consists of two single fragments (~3% of each) of dacitic lava with sieved plagioclase-coarse orthopyroxene-clinopyroxene phenocrysts and a dacitic lava with hourglass sector-zoned clinopyroxene phenocrysts. |
| R-7 927-932 2- to 4-mm size fraction | This polished thin section contains a heterogeneous mixture of clinopyroxene-porphyritic vesicular vitric dacite (21%), fine-grained feldspar-biotite dacite (11%), a heavily silicified volcanic lithology (11%), and a red-glass pumice with fine-grained feldspar laths (11%). The remainder of the section consists of eight single fragments (~5% of each) of aphyric vitric pumice, sanidine porphyritic vitric pumice, plagioclase-sanidine-quartz porphyritic vitric pumice, a heavily clay-altered red volcanic lithology, a plagioclase-quartz-biotite porphyritic dacite lava, a clinopyroxene-red amphibole porphyritic dacite lava, a coarse clinopyroxene-plagioclase porphyritic dacite, and a fine-grained plagioclase-amphibole vesicular vitric dacite. |
| R-7 972-977 Hand-picked fragments | This polished thin section consists entirely of vitric pumice with rare phenocrysts of plagioclase, sanidine, and quartz. Partial clay alteration is evident within pumice vesicles. |
| R-7 982-987 2- to 4-mm size fraction | This polished thin section consists predominantly of brown volcanic siltstone pellets (20%) plus dacitic lava with acicular orthopyroxene-clinopyroxene phenocrysts (11%), spherulitic devitrified lava (11%), massive to flow-banded devitrified rhyolite lava (11%), blocky orthopyroxene-clinopyroxene porphyritic dacite lava (11%), fine-grained trachytic lava (8%), amphibole-clinopyroxene porphyritic dacite lava (8%), and a devitrified aphyric lava (85). The remainder of the section consists of three single fragments (~4% of each) of hematite-altered dacitic lava, dacitic lava with plagioclase and zoned red clinopyroxene phenocrysts, and a heavily clay-altered lava. |
| R-7 1047-1052 pum Hand-picked fragments | This polished thin section consists entirely of vitric pumice with rare phenocrysts of subhedral plagioclase, anhedral sanidine, and traces of yellow-brown biotite. |

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|---|---|
| R-7 1057-1062<br>2- to 4-mm size fraction | This polished thin section contains a heterogeneous mixture of fine-grained clinopyroxene-dominant dacite (38%), fine-grained orthopyroxene-clinopyroxene dacite lava (11%), dacite lava with amphibole and concentrically zoned clinopyroxene phenocrysts (11%), and dacitic lava with coarse biotite and fine-grained clinopyroxene phenocrysts (8%). The remainder of the section consists of eight single fragments (~4% of each) of plagioclase-rich perlitic dacitic lava, amphibole-clinopyroxene porphyritic dacitic red-glass lava, altered dacitic lava with coarse plagioclase, clinopyroxene-amphibole porphyritic dacite, dacitic lava with red pyroxene and sieved plagioclase phenocrysts, heavily silicified and oxidized lava, a dacitic flow breccia with altered amphibole phenocrysts, and a hornblende-porphyritic dacite. |
| R-7 1087-1092<br>2- to 4-mm size fraction | This polished thin section contains a heterogeneous mixture of dacitic lavas (68%), Precambrian lithologies (16%), and devitrified welded tuffs (16%). Dacitic components include plagioclase-porphyritic feldspathic lava (16%), clinopyroxene-orthopyroxene porphyritic dacitic lava (8%), red dacitic flow breccia with plagioclase and biotite phenocrysts (8%), amphibole-clinopyroxene porphyritic dacitic lava (8%), and seven single fragments (~4% of each) of biotite dacite, sieved plagioclase-clinopyroxene-biotite porphyritic dacitic lava, aphyric lava (probably dacitic), red-matrix clinopyroxene-porphyritic dacitic lava, spherulitic devitrified plagioclase-porphyritic lava, heavily silicified clinopyroxene dacitic lava with chalcedony void fillings, and an unidentifiable silicified lava. Precambrian components include fine-grained sutured quartzite (12%) and a single fragment (~4%) of muscovite-biotite-microcline granite. Devitrified welded tuffs include a crystal-rich plagioclase-clinopyroxene-biotite porphyritic tuff (8%) and quartz-sanidine porphyritic silicified tuff (8%). |
| R-7 1092-1097a<br>4- to 8-mm size fraction | This polished thin section contains a heterogeneous mixture of dacitic to basaltic lavas (68%), Precambrian quartzite (24%), and devitrified welded tuff (8%). Dacitic components include clinopyroxene-biotite porphyritic dacite lava (20%), amphibole-porphyritic dacite with minor biotite and altered clinopyroxene phenocrysts (16%), dacitic lava with sparse relict clinopyroxene (8%), and six single fragments (~4% of each) of clay-altered dacitic lava with relict amphibole phenocrysts, dacitic lava with altered clinopyroxene and orange clay, microspherulitic devitrified felsic lava, plagioclase-clinopyroxene-biotite porphyritic lava with red glass matrix, biotite-porphyritic lava, and a clinopyroxene-porphyritic basalt with altered olivine, altered amphibole, and a polycrystalline quartzite xenolith. The Precambrian quartzites are sutured, and the devitrified welded tuffs contain sparse sanidine phenocrysts. |
| R-7 1092-1097b<br>2- to 4-mm size fraction | This polished thin section contains a mixture of dacitic to basaltic lavas (65%) and Precambrian lithologies (33%), plus one fragment (~2%) of vitric aphyric pumice. Dacitic components are similar to those of the 4-8 mm size fraction. The Precambrian lithologies are varied, including quartzites (25%) that are sutured or polygonal, some with biotite, muscovite, and/or kyanite, and granitic lithologies (8%) that have muscovite or muscovite-biotite associations. |
| R-7 1092-1097a<br><2-mm size fraction | This polished thin section contains rounded single grains of quartz, plagioclase, microcline, clinopyroxene, and rarer sanidine, myrmekite, biotite, and amphibole. Lithic grains include fine-grained dacitic lava matrix, quartzite, less common granitic fragments, and vitric aphyric pumice. |

# Appendix D

*Modifications to Work Plans*

**Table D-1**
**Activities Planned* for R-7 Compared with Work Performed**

| Activity | Hydrogeologic Workplan | R-7 Field Implementation Plan | R-7 Actual Work |
|---|---|---|---|
| **Planned Depth** | 100 to 500 ft into the regional aquifer | Approximately 1300 ft or 50 ft into the Santa Fe Group basalt, whichever comes first | Total drill depth 1097 ft, approximately 194 ft below the regional water table |
| **Drilling Method** | Methods may include, but are not limited to HSA, air-rotary/Odex/Stratex, air-rotary/Barber rig, and mud-rotary drilling. | Hollow-stem auger and casing advance/open hole, air-rotary equipment | Hollow-stem auger and casing advance/open hole, air-rotary equipment |
| **Amount of Core** | 10% of the borehole | No core planned | No core attempted |
| **Lithologic Log** | Log to be prepared from core, cutting, and drilling performance | Log to be prepared from cuttings, geophysical logs, and drilling performance | Log from cuttings, geophysical logs, and drilling performance |
| **Number of Water Samples Collected for Contaminant Analysis** | A water sample may be collected from each saturated zone, five zones assumed. The number of sampling events after well completion is not specified. | A water sample is to be collected from each saturated zone. The geochemistry project leader and technical team will determine the number and locations of samples based on conditions encountered. The number of sampling events after well completion is not specified. Up to five water samples are planned. | Two water samples were obtained. Water was collected from a perched zone at 373 ft bgs. Water at the top of the regional water table was sampled at 903 ft bgs. |
| **Water Sample Analysis** | Initial sampling: Radiochemistry I, II, and III, $^{3}H$, general inorganics, stable isotopes, VOCs, and metals<br><br>Saturated Zones: radionuclides (tritium, Sr-90, Cs-137, Am-241, plutonium isotopes, uranium isotopes, gamma spectrometry, and gross alpha, beta, and gamma), stable isotopes (hydrogen, oxygen, and, in special cases, nitrogen), major ions (cations and anions), trace metals, and trace elements | **Trace Elements/Metals**<br>**Anions:** Br, Cl, Fl, $PO_4$, $SO_4$, $NO_3$, $NO_2$, $NH_4$<br>**Major Cations**<br>**Other Inorganic Chemicals:** cyanide<br>**Stable and Radiogenic Isotopes:** $^{18}O/^{16}O$, D/H, $^{15}N/^{14}N$<br>**Radionuclides:** $^{3}H$, $^{90}Sr$, $^{241}Am$, $^{137}Cs$, $^{238}Pu$, $^{239,240}Pu$, $^{234}U$, $^{235}U$, $^{238}U$, gamma spectrometry, gross-alpha, gross-beta, gross gamma<br>**Organic Compounds:** volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), pesticides/polychlorinated biphenyls (PCBs), high explosives (HE), humic acid, total organic carbon (TOC) | **Trace Elements/Metals**<br>**Anions:** Br, Cl, Fl, $PO_4$, $SO_4$, $NO_3$, $NO_2$, $NH_4$<br>**Major Cations**<br>**Other Inorganic Chemicals:** cyanide<br>**Stable and Radiogenic Isotopes:** $^{18}O/^{16}O$, D/H, $^{15}N/^{14}N$<br>**Radionuclides:** $^{3}H$, $^{90}Sr$, $^{241}Am$, $^{137}Cs$, $^{238}Pu$, $^{239,240}Pu$, $^{234}U$, $^{235}U$, $^{238}U$, gamma spectrometry, gross-alpha, gross-beta, gross gamma<br>**Organic Compounds:** VOCs, PAHs, pesticides/PCBs, HE, humic acid, TOC |

**Table D-1 (continued)**

| Activity | Hydrogeologic Workplan | R-7 Field Implementation Plan | R-7 Actual Work |
|---|---|---|---|
| **Water Sample Field Measurements** | Alkalinity, pH, specific conductance, temperature, turbidity | pH, specific conductance, temperature, turbidity | pH, specific conductance, temperature, turbidity |
| **Number of Core/Cuttings Samples Collected for Contaminant Analysis** | Twenty samples of core or cuttings to be analyzed for potential contaminant identification in each borehole | Up to five core/cuttings samples are planned; the number of samples will be dependent on the number of saturated zones encountered. | No core or cuttings samples submitted for contaminant analysis |
| **Core Sample Analytes** | Uppermost sample will be analyzed for a full range of compounds: Deeper samples will be analyzed for the presence of radiochemistry I, II, and III analytes, tritium (low and high detection levels), and metals. Four samples will be analyzed for VOCs. | No core sampling planned | No core obtained |
| **Laboratory Hydraulic-Property Tests** | Physical properties analyses will be conducted on five core samples and will typically include moisture content, porosity, particle density, bulk density, saturated hydraulic conductivity, and water retention characteristics. | No laboratory testing planned | No samples submitted |
| **Geology** | Ten samples of core or cuttings will be collected for petrographic, x-ray fluorescence (XRF), and x-ray diffraction (XRD) analyses. | The geology task leader will determine the number of samples for characterization of mineralogy, petrography, and rock chemistry based on geologic and hydrologic conditions encountered during drilling. | Twenty-seven samples were characterized for mineralogy, petrography, and rock chemistry. |

**Table D-1 (continued)**

| Activity | Hydrogeologic Workplan | R-7 Field Implementation Plan | R-7 Actual Work |
|---|---|---|---|
| **Geophysics** | In general, open-hole geophysics includes caliper, electromagnetic induction, natural gamma, magnetic susceptibility, borehole color videotape (axial and sidescan), fluid temperature (saturated), single-point resistivity (saturated), and spontaneous potential (saturated).<br>In general, cased-hole geophysics includes gamma-gamma density, natural gamma, and thermal neutron. | In general, open-hole geophysics includes caliper, electromagnetic induction, natural gamma, magnetic susceptability, borehole color videotape, fluid temperature (saturated), fluid resistivity (saturated), and spontaneous potential (saturated).<br>In general, cased-hole geophysics includes: gamma-gamma density, natural gamma, and thermal neutron. | Video (LANL tool): 0 to 849 ft, and 0 to 977 ft bgs. Natural gamma (LANL tool): 0 to 972 ft, and 0 to 977 ft bgs. Schlumberger geophysics (0 to 290 ft cased, 290 to 1064 ft open hole): Litho density, Gamma Ray, Caliper, Combinable Magnetic Resonance, Formation Micro Imager, Spectral Gamma, Thermal/Epithermal Neutron, Array Induction, and Natural Gamma |
| **Water-Level Measurements** | Procedures and methods are not specified in the hydrogeologic workplan. | Water levels will be determined for each saturated zone by water-level meter or by pressure transducer. Additional water-level readings are to be made at as many borehole depths as possible for vertical gradient determination. | A water-level meter determined the water levels for the regional water table. Water levels in the perched water zones (screened at 363.2 to 379.2 ft bgs and 730.4 and 746.4 ft bgs) were not measured during drilling. |
| **Field Hydraulic-Property Tests** | Not specified in hydrogeologic workplan | Slug or pumping tests may be conducted in saturated intervals once the well is completed. | None conducted |
| **Surface Casing** | Approximately 20-in. O.D., extends from land surface to 10-ft depth in underlying competent layer; grouted in place. | 18-in.-O.D. steel casing will be installed and cemented in place to isolate the borehole from surface water and alluvial groundwater. (No specific depth given.) | 18-in.-O.D. steel casing set at 12 ft and cemented in place. |
| **Minimum Well Casing Size** | 6-5/8-in. O.D. | 5.56-in. O.D. | 5.56-in.-O.D. (4.5-in.-I.D.) stainless steel casing with external couplings |
| **Well Screen** | Machine-slotted (0.01-in.) stainless-steel screens with flush-jointed threads; number and length of screens to be determined on a site-specific basis and proposed to NMED | Well screen shall be constructed with multiple sections of 5.56-in. O.D. stainless steel. | Screened intervals constructed of 5.56-in.-O.D. (4.5-in.-I.D.) pipe-based, stainless-steel, wire-wrapped, 0.010-in slotted screen |

**Table D-1 (continued)**

| Activity | Hydrogeologic Workplan | R-7 Field Implementation Plan | R-7 Actual Work |
|---|---|---|---|
| **Filter Material** | >90% silica sand, properly sized for the 0.010-in. slot size of the well screen; extends 2 ft above and below the well screen | Primary filter pack shall consist of round, clean, washed and resieved silica sand with a uniformity coefficient of 2.0 or less, placed 10 ft above and 5 ft below the well screen. The size of the filter pack shall be selected based on the characteristics of the formation to be screened. Secondary filter pack is finer (30/70) silica sand placed 3 ft below and 5 ft above the primary pack. | Primary filter pack constructed of 20/40 silica sand placed 5 to 10 ft below and 5 to 16 ft above the screen<br><br>Secondary filter pack of 30/70 silica sand constructed in a nominal 2-ft-thick layer above and below the primary filter pack |
| **Conductor Casing** | Carbon-steel casing from land surface to top of stainless-steel casing | Carbon-steel casing 5.56-in. in diameter extending from land surface to dielectric coupling at top of stainless-steel casing | Carbon-steel casing from land surface to top of stainless-steel casing |
| **Backfill Material (exclusive of filter materials)** | Uncontaminated drill cuttings below sump, and bentonite above sump | Bentonite in borehole below well; fine sand in transition zone; bentonite above transition zone to bottom of surface casing; cement grout between surface casing and borehole wall and between surface casing and well casing | Washed gravel in borehole below well casing; bentonite seal below filter pack; bentonite and 6/9 or 8/12 sand mixture or bentonite and washed gravel mixture between filter packs; four cement grout plugs and cement from surface to 79 ft bgs |
| **Sump** | Stainless-steel casing with an end cap | 5.56-in.-diameter stainless-steel casing 30 ft long | 5.56-in.-diameter stainless-steel casing 40 ft long |
| **Bottom Seal** | Bentonite | Bentonite | Bentonite |

*Note:* The Task/Site Work Plan for Operable Unit 1049 Los Alamos Canyon and Pueblo Canyon, November 1995, is not included as a column in this table because it only includes plans for intermediate-depth borehole and well installation.

# Appendix E

*Westbay$^{TM}$ MP 55 Well Components Installed in R-7*

# Summary Casing Log

**Company: Los Alamos National Lab**
**Well: R-7**
**Site: LANL**
**Project: Hydrogeology Study**

**Job No: WB777**
**Author: DL/SP**

## Well Information

Reference Datum: Ground Level
Elevation of Datum: 0.00 ft.
MP Casing Top: 0.00 ft.
MP Casing Length: 970.96 ft.
Depth Adjusted For:
Field De-Stressing
Well Description:
PlasticMP55
Other References:
Pipe-based wire-wrapped screens.
BF and screens after LANL 02/08/01

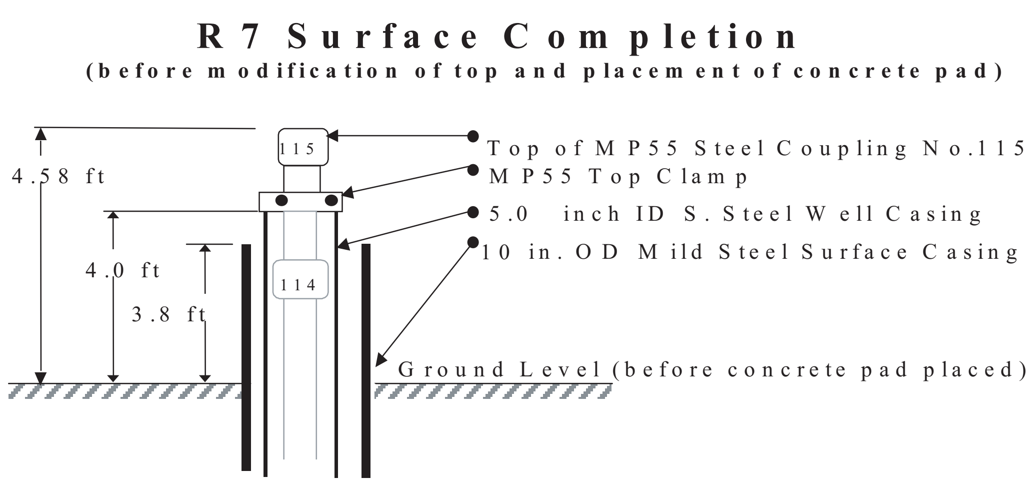
Borehole Depth: 1097.00 ft.
Borehole Inclination: vertical
Borehole Diameter: 5.00 in.

## File Information

File Name: 777_R7.WWD
Report Date: Sun Mar 11 19:55:33 2001

File Date: Mar 11 19:36:09 2001

## Sketch of Wellhead Completion



Summary MP Casing Log
Los Alamos National Lab

Job No: WB777
Well: R-7

# Legend

## (Qty) MP Components

(Library - WD Library 7/27/00)

(2) 0603 - MP55 End Plug

(85) 0601M30 - MP55 Casing, 3.0 m, PVC

(14) 0601M15 - MP55 Casing, 1.5 m, PVC

(9) 0612 - MP55 Packer, Stiffened, SS

(6) 0601M10 - MP55 Casing, 1.0 m, PVC

(100) 0602 - MP55 Regular Coupling

(13) 0605 - MP55 Measurement Port

(3) 0607 - MP55 Hydraulic Pumping Port

(5) 0608 - MP55 Magnetic Location Collar

## Geology

## Backfill/Casing

Concrete

Bentonite, Sand

Grout

Sand Fine

Sand Coarse

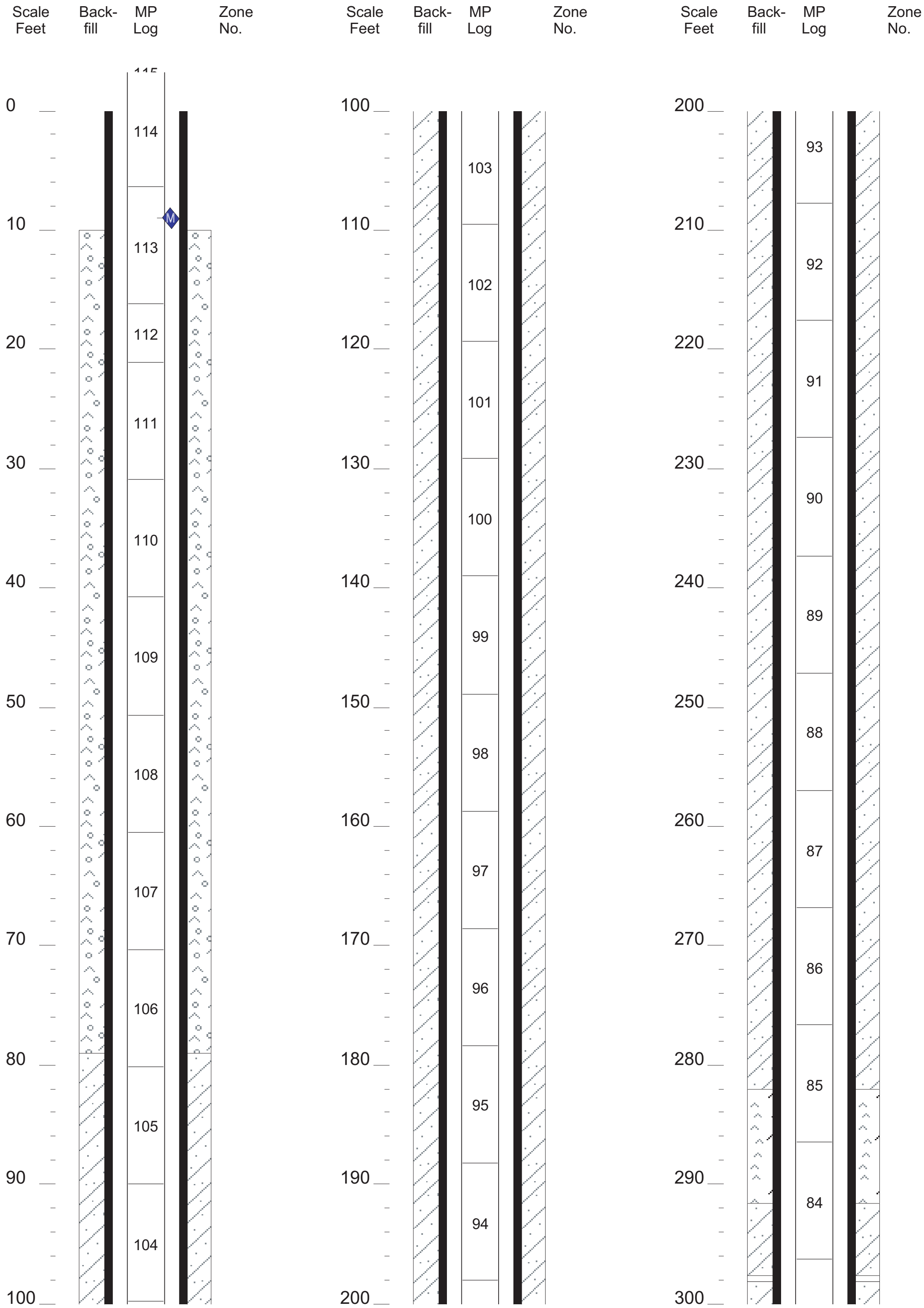
Stainless Steel

Well Screen

 Sun Mar 11 20:01:08 2001 Page: 1

Summary MP Casing Log
Los Alamos National Lab

Job No: WB777
Well: R-7

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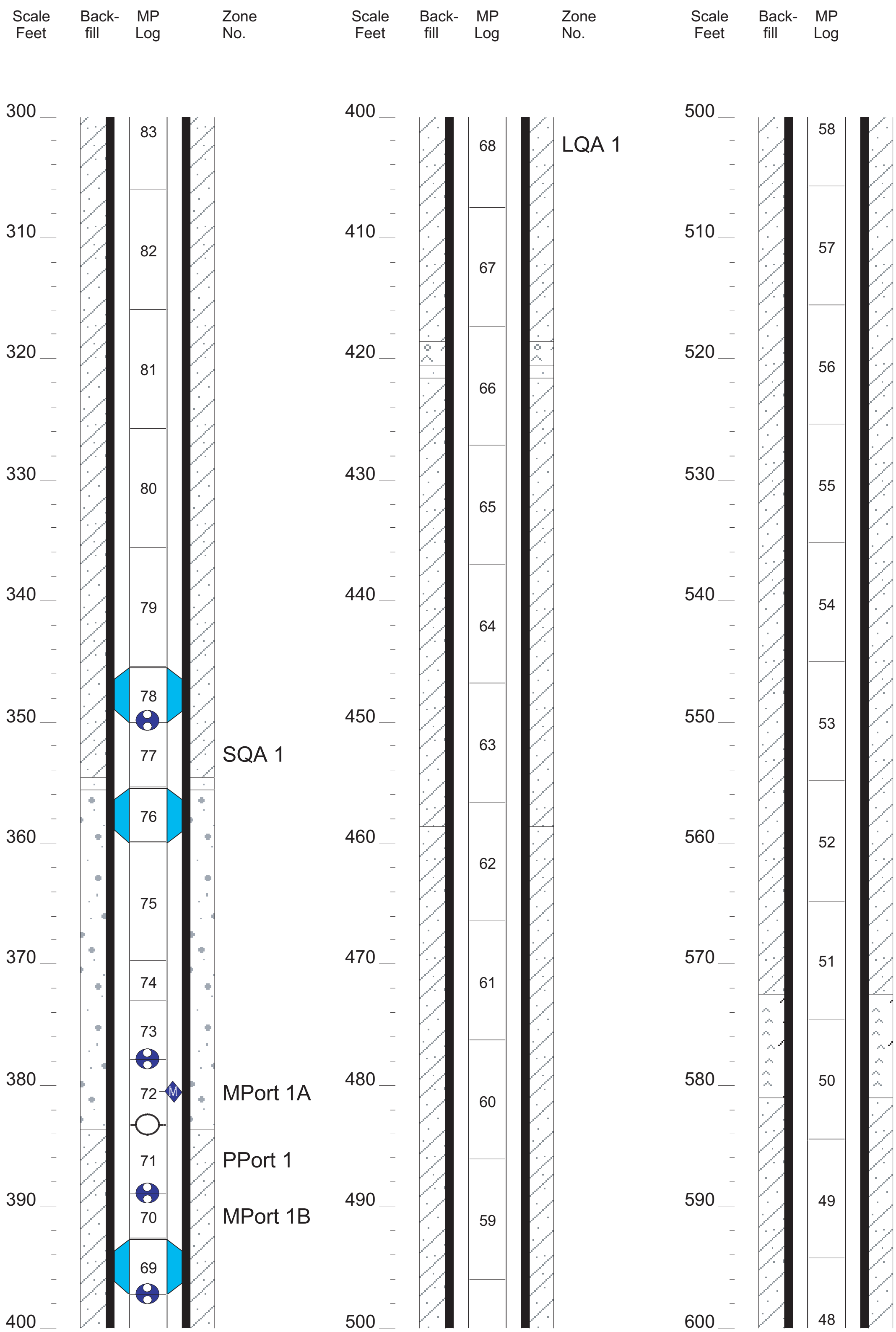
Summary MP Casing Log
Los Alamos National Lab

Job No: WB777
Well: R-7

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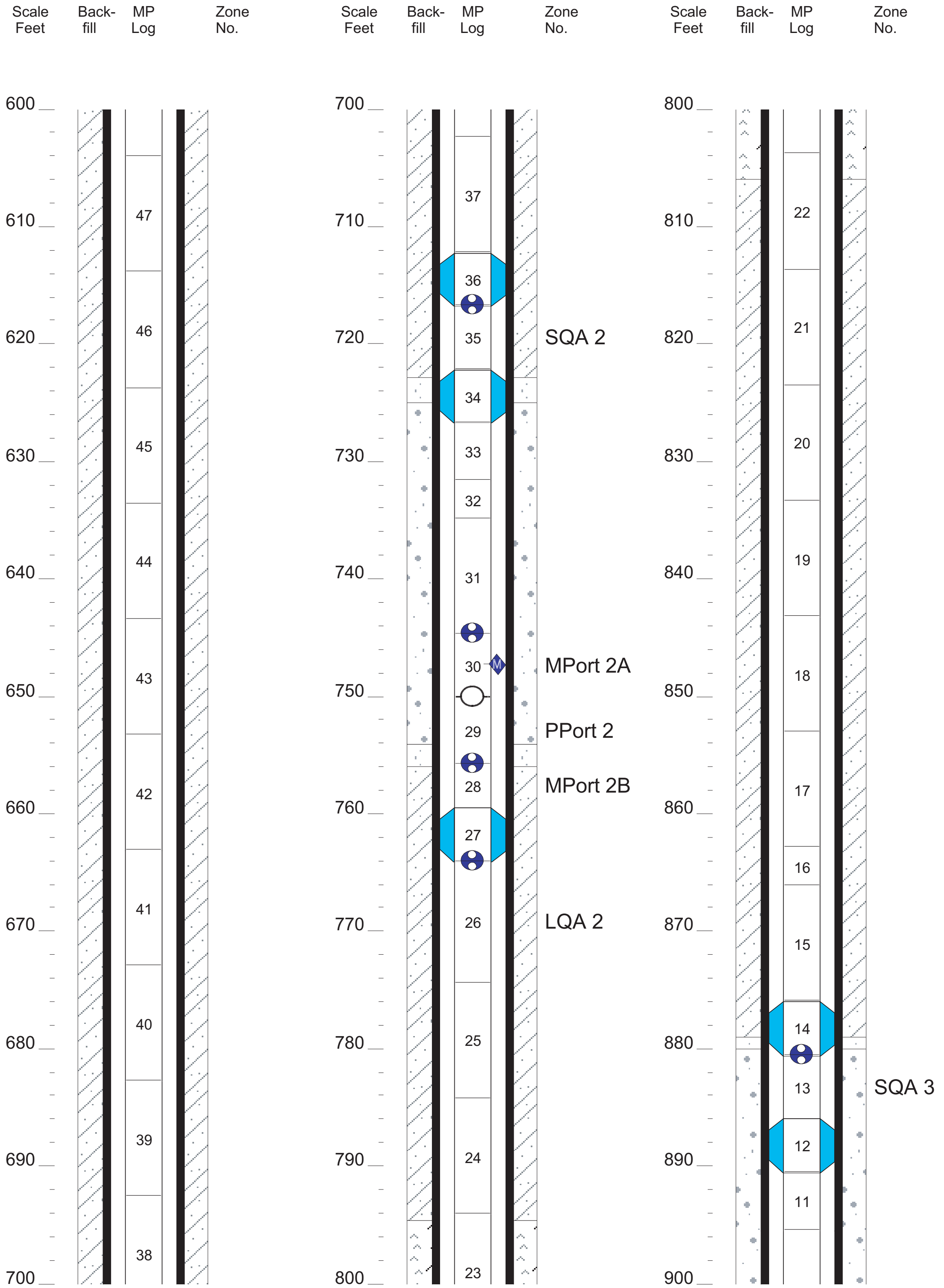
Summary MP Casing Log
Los Alamos National Lab

Job No: WB777
Well: R-7

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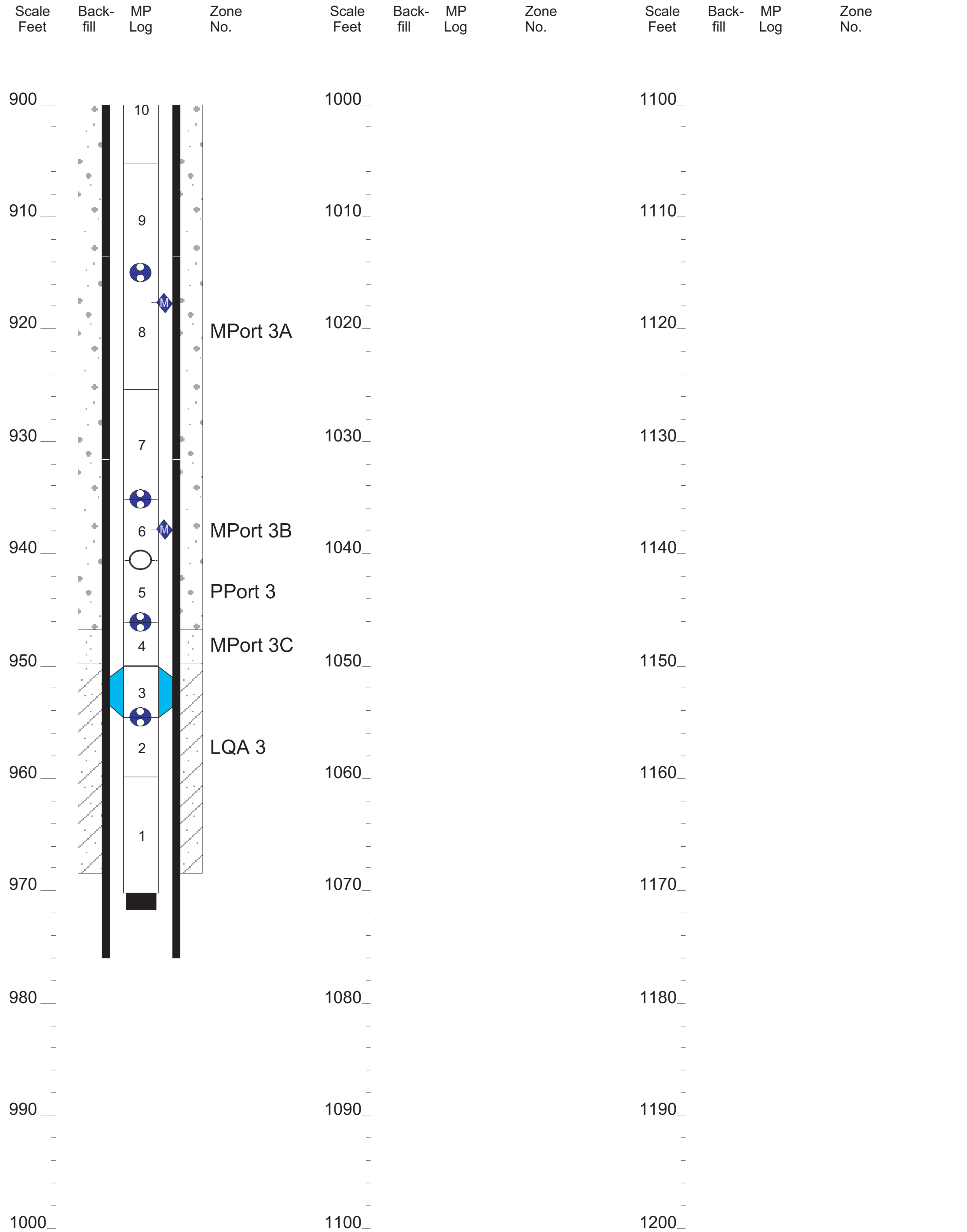
Summary MP Casing Log
Los Alamos National Lab

Job No: WB777
Well: R-7

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